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Rice and Sturgeon Lakes Nutrient Budget Study

Water Chemistry Data for Rice Lake, Sturgeon Lake and their Respective Catchments 1986-1989

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WATER CHEMISTRY DATA FOR RICE LAKE, STURGEON LAKE AND THEIR RESPECTIVE CATCHEMENTS

1986 - 1989

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WATER CHEMISTRY DATA FOR RICE LAKE, STURGEON LAKE AND THEIR RESPECTIVE CATCHMENTS

1986 - 1989

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Note: All references to Water Resources Branch in this report should read Science and Technology Branch

PREFACE

The Kawartha lakes are a large and economically important system of eight large lakes which are located in central Ontario. Sturgeon Lake and Rice Lake are located near the upper and lower ends of the Kawartha Lakes system respectively and both support significant amounts of urban and recreational development. They were chosen for detailed study because of their importance within the system and because both have shown the symptoms associated with excessive nutrient input for several years.

The Rice and Sturgeon Lakes Nutrient Budget Study was initiated to investigate linkages between point and non-point sources of nutrients, water quality, and aquatic life within the lakes and to estimate the impacts of these processes on in-lake water quality.

The study was supervised by the Rice - Sturgeon Lakes Nutrient Budget Technical Committee which had representatives from the Limnology Section (Water Resources Branch) and Central Region of the Ontario Ministry of the Environment and Energy, the Trent Severn Waterway (Environment Canada) and the Kawartha Lakes Fisheries Assessment Unit of the Ontario Ministry of Natural Resources.

This is one of a series of technical reports. These and the summary report (R/S Tech. Rep. No. 13) will provide a technical basis for the management of the Rice Lake and Sturgeon Lake ecosystems and for the use of land and water resources in the Kawartha Lakes region in general. A list of all reports in the R/S Tech. Rep. series is as follows:

1. Hutchinson N.J., B.J. Clark,, J.R. Munro and B.P. Neary 1993. Hydrological data for the watersheds of Rice Lake and Sturgeon Lake.1986 - 1989, 100 pp.

2. Hutchinson N.J., J.R. Munro, B.J. Clark and B.P. Neary. 1993. Water chemistry data for Rice Lake, Sturgeon Lake and their respective catchments. 1986-1989, 169 pp.

3. Hutchinson N.J., B.P. Neary, B.J. Clark and J.R. Munro 1993. Nutrient Budget data for the watersheds of Rice Lake and Sturgeon Lake. 120 pp.

4. Ryback, M. and I. Rybak. 1993. Sediment pigment stratigraphy as evidence of long term changes in primary productivity of Sturgeon and Rice Lakes (Kawartha Lakes). 24 pp.

5. Nicholls, K.H., M.F.P. Michalski and W. Gibson. 1993. Trophic interactions in Rice Lake I: An experimental demonstration of effects on water quality.

6. Limnos Ltd. 1993. Partitioning of phosphorus in *Potamogeton crispus*. 22 pp.

7. Limnos Ltd. 1993. Rice Lake macrophytes: distribution, composition, biomass, tissue nutrient content and ecological significance. 123 pp.

8. Beak Consultants Ltd. 1993. Release of phosphorus from Rice Lake sediments. 31 pp .

9. Limnos Ltd., Michael Michalski Associates and D.J. McQueen. 1993. Trophic interactions in Rice Lake II. Young-of-the-year yellow perch - *Daphnia* interactions, preliminary findings. 101 pp.

10. Badgery, J.E., D.J. McQueen, K.H. Nicholls and P.R.H. Schaap. 1993. Trophic interactions in Rice Lake III: Potential for biomanipulation. 1988 and 1989 .

11. Standke, S. 1993. The zooplankton of Rice Lake and Sturgeon Lakes, 1986-1988, Kawartha Lakes, Ontario .

12. Nicholls, K.H. 1993. The phytoplankton- water quality relationships of the Kawartha Lakes, 1972-1989.

13. Hutchinson, N.J., K.H. Nicholls and S.H. Maude, 1993. Rice and Sturgeon Lake Nutrient Budget Study: Summary and recommendations.

SUMMARY

Water quality data for Rice and Sturgeon Lakes, their major and minor inflows and their outflows, was collected for the period between April 1, 1986 and May 31, 1989. Measurements were made year-round according to a schedule which increased sampling frequency during high-flow periods. Temperature, dissolved oxygen and water quality were sampled at four locations in Rice Lake and at six locations in Sturgeon Lake, biweekly during the April to October ice-free period. Statistical summaries and distributions of all water quality parameters were determined for each stream site and lake station and concentrations plotted for each year of the study.

No consistent relationship between instantaneous stream discharge and the concentrations of total phosphorus, chloride or potassium was observed. The present water quality in each lake was compared to data collected in 1971 and 1972 to determine any changes in trophic status. An intensive study of total phosphorus and potassium dynamics was conducted for the 10 day period of maximum biomass and senescence of Potamogeton crispus, the dominant aquatic macrophyte in Rice Lake in 1987.

Rice and Sturgeon Lakes are both eutrophic but shallow depth and exposure to prevailing winds provide enough mixing to prevent prolonged anoxia in bottom waters.

Total phosphorus concentrations in Rice Lake appear to have declined and early-spring Secchi depth increased since 1972 but late-summer chlorophyll a concentrations have increased. This may reflect decreased dominance of blue-green algae. Water quality improved from west to east within Rice Lake. Potassium concentrations were closely tied to growth of aquatic macrophytes but phosphorus was not.

Sturgeon Lake had three distinct areas of differing water quality. The north end of the lake was dominated by Precambrian shield drainage from Cameron Lake. The south end of the lake responded to the poor water quality of the Scugog River. The main body of the lake represented an average of these two water qualities. Total phosphorus concentrations have apparently decreased since 1971 at the outflow of Sturgeon Lake but have increased in the north end.

Conclusions about long-term phosphorus trends are in some doubt due to the questionable accuracy of historical measurements. Chloride concentrations in both lakes increased since 1972 but increases between 1986 and 1989 reflect differences in rainfall. Some tributary streams showed detrimental impacts associated with agricultural runoff and land disposal of sewage. Data for total phosphorus, chloride and potassium were combined with daily estimates of discharge to produce nutrient and elemental budgets for each lake in Hutchinson et. al (1993c).

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INTRODUCTION

The Rice and Sturgeon Lakes nutrient budget study was started by MOE in 1986 with the participation of MNR and Parks Canada (Trent Severn Waterway).
The goals of the study were to:

1) Construct detailed nutrient budgets for Rice and Sturgeon Lakes.
2) Link the nutrient inputs and outputs to water quality in each lake and in particular to levels of blue-green and other planktonic algae and to rooted aquatic macrophytes.
3) Estimate the impact of Sturgeon and Rice Lakes on the water quality downstream.
4) Develop a nutrient management plan for each lake and make recommendations on the need for controlling point and non-point source nutrient inputs.

This report presents the detailed and summarized water quality data collected for Rice and Sturgeon Lakes between April 1, 1986 and May 31, 1989. Quantitative water quality data were required as input to the nutrient mass balance model for each lake. Data were also used to assess the water quality in each lake and to identify areas of concern. Seasonal and annual patterns were identified and compared to previous studies (MOE/MNR 1976).

This report presents data on water quality only. Water and nutrient budget data are presented in two separate volumes (Hutchinson et al. 1993a and c). Biological data are given in a series of 9 reports and all data summarized in the final report of the Rice and Sturgeon Lake Study (Hutchinson et al. 1993d).

In June of 1987 an intensive survey of water chemistry in Rice Lake was made during the period of maximum biomass and senescence of Potamogeton crispus, the dominant macrophyte in the lake. This study combined elements of water chemistry, nutrient budget and biology and is presented in its entirety in a separate section of this volume.

DESCRIPTION OF STUDY AREA

Rice and Sturgeon Lakes are two large lakes located in the Kawartha Lakes Region of Ontario. They form part of the Rideau-Trent-Severn waterway, a 680 km corridor of lakes and connecting waterways extending from Port Severn on Georgian Bay to Trenton on the Bay of Quinte and extending northeast to Ottawa. The location of Rice and Sturgeon Lakes is shown in Figure 1.

Sturgeon Lake has a surface area of 4700 ha and drains a watershed area of 476,400 ha (Table 1). The major inflow to Sturgeon Lake is the outlet of Cameron Lake

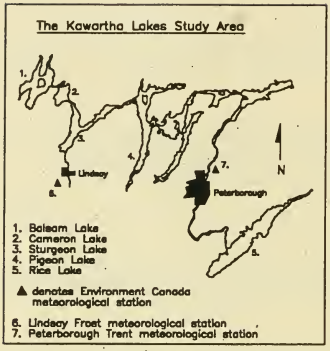

Figure 1: Location of the Rice Lake and Sturgeon Lake study area.

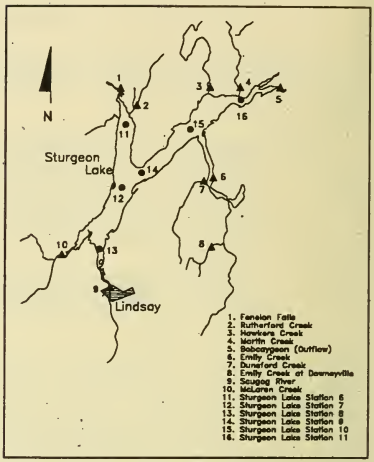

Figure 2: Water quality sampling locations in the Sturgeon Lake watershed.

at Fenelon Falls (Figure 2). Approximately 75% of this drainage is from forested Precambrian Shield areas in the basins of the Gull River and Burnt River, which discharge into Balsam and Cameron Lakes respectively (Hutchinson et. al 1993a). The Scugog River drains Scugog Lake and discharges into Sturgeon Lake at Lindsay. The Scugog River, and the remaining portions of the Sturgeon Lake watershed, drain mixed agricultural, wetland and forested land within the Oak Ridges Moraine, the Till Plain, the Lowland Plain and the Limestone Plateau (Kawartha Region Conservation Authority 1982). Smaller sections of the immediate watershed of Sturgeon Lake are drained by many small streams (Figure 2).

From the outlet of Sturgeon Lake at Bobcaygeon, water flows through Pigeon, Buckhorn, Lower Buckhorn, Lovesick, Stony and Katchewanooka Lakes and enters the Otonabee River at Lakefield. From Lakefield, the Otonabee River flows through Peterborough and empties into Rice Lake at Campbelltown.

The drainage area between Sturgeon and Rice Lakes receives runoff from many creeks including Jack Creek, Eels Creek and the Mississagua River which drain the Precambrian Shield. Most of the drainage, however, is from mixed agricultural, forested and wetland areas overlying till plains and sedimentary rock.

The hydrology of Rice Lake is dominated by the Otonabee River with small inputs from the Indian and Ouse Rivers on the north shore (Figure 3). A total of 58 small creeks flow into Rice Lake from the immediate watershed. Two of these were monitored to estimate runoff from this source.

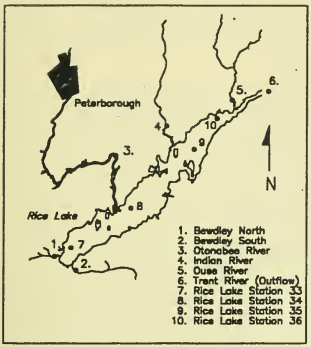

Figure 3: Water quality sampling locations in the Rice Lake watershed.

Rice Lake has a surface area of 10,010 ha and drains a total of 914,000 ha (Table 1). From its outlet, the Trent River near Hastings, water flows to the Bay of Quinte at Trenton and hence to Lake Ontario.

The watershed of Rice Lake is regulated by a series of dams. These are located on every lake in the Trent-Severn system and into the headwaters in Haliburton and Victoria Counties to the north. The Trent-Severn Waterway requires a regulated flow mainly for navigation purposes, but the hydrologic budget is also managed for power generation, flood control, recreation and fisheries .

Table 1: Drainage areas for tributaries and rivers of Rice and Sturgeon Lakes

Watershed		Area (ha)
Rice	Bewdley North	631
	Bewdley South	2220
	Ouse River	28200
	Indian River	25800
	Otonabee River	822530
	Trent River	914120
	Ungauged Area	24734
Sturgeon	Mclaren Creek	5339
	Hawkers Creek	4433
	Martin Creek	3473
	Rutherford Creek	1823
	Dunsford Creek	2439
	Emily Creek	16697
	Scugog River	96370
	Fenelon Falls	324500
	Big Bob Channel	476377
	Ungauged Area	19032

*Emily Creek at Downeyville was monitored as part of the Sturgeon Lake hydrology network but only occasional water quality samples were taken.

The climate of the Kawartha Lakes system is described as humid continental and is located within the Simcoe-Kawartha Lakes climatic zone (KRCA 1982). Long term (1951-1980) annual precipitation is 850 mm per year, 20-25% of which falls as snow between November 1 and April 30 (Table 2, from Env. Canada, 1981). Average daily temperature is 19.75°C for July and -8.85°C for January. Runoff depth is 300 mm per year (Fisheries & Env. Canada, 1978).

METHODS

Water quality was monitored within each lake, its major inflows and outflows, several representative small inflow streams and in precipitation. These measurements were made to determine:

1. The total load of nutrients into and out of each lake.
2. The contribution of individual watersheds to the nutrient budget.
3. The responses of lakes and tributaries to point and non-point source nutrients.
4. The interactions between the biotic community and nutrients in each lake.

Specific point and non-point sources of nutrients were estimated by separate methods (Hutchinson et al. 1993c)

Lake Sampling

Three sampling regimes were followed for lakes. Routine sampling consisted of euphotic zone (2X Secchi depth) composite samples at four sites on Rice Lake (Fig. 3, Table 3) and six sites on Sturgeon Lake (Fig. 2, Table 3) at three week intervals during the ice free period of each study year. Under ice samples were taken in February of 1987 and 1989 at the deep station on each lake. Sample frequency was intensified on Rice Lake during the peak in growth and senescence of

Table 2: Summary of long-term hydrometeorological characteristics of the Rice and Sturgeon Lakes Study area.

Temperature	Lindsay	Peterborough
Average Daily (July)	19.7	19.8
Average Daily (Jan)	-8.9	-8.8
Precipitation		
Rainfall (mm)	656.3	642.2
Snowfall (water equiv. mm)	201.9	161.7
Total Precipitation (mm)	856.4	797.7
Std. Dev. Total Precipitation	105.1	98.3

Potamogeton crispus in June & July. Four stations were sampled weekly between early June and mid-July of 1986-88. Daily measurements of nutrient concentration were made at 43 sites on Rice Lake for ten days in 1987. These results are discussed separately from the routine water quality results. Finally, Rice Lake water quality was sampled within each of the limnocorrals set up in 1986 and 1987. These measurements are summarized in a separate report (Michalski et al. 1991). Tributary water quality was measured year round from 1986 to 1988 with most sampling emphasis during periods of high flow.

Historical Comparisons

Long-term changes in the trophic status of Rice and Sturgeon Lakes were determined from the results of surveys carried out in 1971 and 1972 by staff of the MOE "Recreational Lakes" program. In both lakes, euphotic zone composite samples were analyzed for total phosphorus (TP), chlorophyll a and Secchi depth.

Five stations on Sturgeon Lake were sampled in June, August and September of 1971. Stations 7, 9 and 8 from 1971 were closest to Stations 6, 7 and 9, respectively, from the present study. Stations 10 and 11 were in the same location for both studies. Between-year comparisons were made using these station pairs. Station 8 from the present study was not sampled in 1971. The original data from this survey were not available so comparisons were made using seasonal minimum and maximum values presented in Ontario Ministry of the Environment (1971). Data from June, August and September surveys in the present study were averaged for each station for comparison with the 1971 data.

Long-term changes in the water quality of Sturgeon Lake were also assessed using data from the provincial water quality monitoring network of MOE. The outlet of Sturgeon Lake to the Big Bob Channel at Bobcaygeon was sampled 1-2 times per month between 1971 and 1991 as part of this monitoring program, providing the best record of long-term changes.

Four stations on Rice Lake were sampled in June, August and September of 1972 (Ministry of the Environment 1972). The locations of the 1972 sampling sites did not match those of the present study. Since between-station differences were either not significant (1972) or minor (see Table 13) data from all stations were pooled for each month for comparison.

Water Chemistry

Analyses of phosphorus and nitrogen were emphasized in lakes and tributaries. Because they are non-conservative, they have rapid responses to in-lake activities and watershed events such as rainstorms. Secchi depth, silica and chlorophyll *a* were measured as other trophic status indicators in lakes but not in tributary inflows. Chlorophyll *a* was also measured at the outflows of Sturgeon and Rice Lakes. Remaining lake parameters (Table 4) were measured as part of the routine limnological survey of the Kawartha Lakes. Potassium was measured as a nutrient having a slower response to plant activity than phosphorus. Sodium and chloride are conservative ions measured to check the mass balance budget for phosphorus (Hutchinson et al. 1993c)

Tributary Sampling

The tributary water quality sampling program was designed to measure nutrient flux through the major inflows

Table 3: Morphometric data for Rice and Sturgeon Lakes and depths at each water quality sampling location.

Rice Lake		
Latitude		44° 12'
Longitude		78° 10'
Surface Area		10010 ha
Watershed Area		914125 ha
Mean Depth		2.4 m
Volume		2.402 * 10^8 m^3
Water Residence Time		34 days
Station RE33	Depth = 5.0 m	
Station RE34	Depth = 3.5 m	
Station RE35	Depth = 6.0 m	
Station RE36	Depth = 8.0 m	
Sturgeon Lake		
Latitude		44° 28'
Longitude		78° 43'
Surface Area		4710 ha
Watershed Area		476377 ha
Mean Depth		3.5 m
Volume		1.649 * 10^8 m^3
Water Residence Time		39 days
Station SN6	Depth = 5.0 m	
Station SN7	Depth = 3.0 m	
Station SN8	Depth = 3.0 m	
Station SN9	Depth = 10.0 m	
Station SN10	Depth = 8.0 m	

Table 4: Water chemistry parameters, detection limits and precision of analyses for samples from Ric and Sturgeon Lakes water quality monitoring network: 1986-1989.

Parameter	Fraction	Detection Limit(mg/L)	Coefficient of Variation(%)
Conductivity	($\mu S.cm^{-1}$)	0.2	8.9
Sodium (Na)	(unfiltered reactive)	0.02	7.2
Potassium (K)	(unfiltered reactive)	0.02	7.4
Chloride (Cl)	(unfiltered reactive)	0.05	7.1
Phosphorus (TP)	(unfiltered total)	0.002	24.4
Phosphate(PO_4)	(fractionated reactive)	0.0005	22.7
Kjeldahl Nitrogen (TKN)	(unfiltered reactive)	0.02	9.9
Total Ammonium (NH_4)	(fractionated reactive)	0.002	15.1
Total Nitrate (NO_3)	(fractionated reactive)	0.02	10.8
Nitrite (NO_2)	(fractionated reactive)	0.001	19.2
Chlorophyll *a* **	(acidified-corrected)	0.001	---
Chlorophyll *a* **	(total)	0.0002	---

All values are from Wright (1987) except those marked as "**" which are from Zanette (1989).

and outflows of each lake, and to use minor tributaries to estimate nutrient loading from ungauged areas. Sampling was done at six locations for Rice Lake (Figure 3, Table 5) and at eight locations for Sturgeon Lake (Figure 2, Table 5). Water quality samples were collected regularly by hired observers near each location, and less frequently by the contractor hired to maintain the hydrology network.

Table 5: Name, location and SIS station location code for tributary and in-lake water quality monitoring stations for the Rice and Sturgeon Lakes Study: 1986-1989.

Station	Location	SIS Location Code
Rice Lake		
Bewdley North (BYN)	Unnamed creek at Hwy.28, North of Bewdley, Ont.	17 0021 535 02
Bewdley South (BYS)	Unnamed creek at C.R.9, South of Bewdley, Ont.	17 0021 536 02
Indian River (IR1)	Indian River at C.R. 2, Keene, Ont.	17 0021 006 02
Ouse River (OE1)	Ouse River at C.R. 2, Birdsalls, Ont.	17 0021 120 02
Otonabee River (OT1)	Otonabee River at Campbelltown Public Wharf.	17 0021 613 02
Trent River (TT1)	Trent River at Hwy. 45, Hastings, Ont.	17 0021 067 02
Lake Station 33 (RE33)	Rice Lake near Bewdley	17 0021 537 01
Lake Station 34 (RE34)	Rice Lake near Spook Island	17 0021 538 01
Lake Station 35 (Re35)	Rice Lake near Hickory island	17 0021 539 01
Lake Station 36 (RE36)	Rice lake near Margaret Island	17 0021 540 01
Sturgeon Lake		
McLaren Creek (MI1)	McLaren Creek at 1st Conc. upstream of Hwy. 35.	17 0021 124 02
Rutherford Creek (RD1)	Rutherford Creek at C.R. 10.	17 0021 125 02
Hawkers Creek (HK1)	Hawkers Creek at C.R. 8.	17 0021 123 02
Martin Creek (MN1)	Martin Creek at C.R. 8.	17 0021 122 02
Emily Creek (EY1)	Emily Creek at Hwy. 36.	17 0021 121 02
Fenelon Falls (CA1)	Cameron Lake Outflow at Hwy. 121, Fenelon Falls.	17 0021 023 02
Scugog River (SG1)	Scugog River at Lock 33, Lindsay.	17 0021 617 02
Scugog River (SG2)	Scugog River at old Railway Bridge, Lindsay.	17 0021 612 02
Big Bob Channel (BB1)	Sturgeon Lake Outflow at Hwy. 36, Bobcaygeon.	17 0021 021 02
Lake Station 6 (SN6)	Sturgeon Lake near Buoy C559.	17 0021 541 01
Lake Station 7 (SN7)	Sturgeon Lake, mid-lake near Snug Harbour.	17 0021 542 01
Lake Station 8 (SN8)	Sturgeon Lake near Buoy CP45.	17 0021 543 01
Lake Station 9 (SN9)	Sturgeon Lake off Sturgeon Point.	17 0021 544 01
Lake Station 10 (SN10)	Sturgeon Lake, mid-lake near Thurstonia Park.	17 0021 545 01
Lake Station 11 (SN11)	Sturgeon Lake near Buoy C590.	17 0021 546 01

Each sampling location was incorporated into the Station Description file of the MOE Sample Information System with an individual 11-digit station ID number (Table 5).

Table 6: Land use classifications and areas for sub-watersheds of Rice and Sturgeon Lakes. Areas are given as percent of total sub-watershed area.

	Agriculture	Dry Wooded	Wet Wooded	Marsh	Urban
Rice Lake					
Bewdley North	47	53	0	0	0
Bewdley South	93	7	0	0	0
Indian River	69	8	14	6	0
Ouse River	53	9	36	2	1
Sturgeon Lake					
Emily Creek	65	12	17	2	1*
Martin Creek	44	46	10	0	0
Hawkers Creek	53	36	10	1	0
Rutherford Creek	62	29	9	0	0
McLaren Creek	77	7	12	6	0**

* Emily Creek sub-watershed includes 1% lake and 2% river area.
** McLaren Creek sub-watershed includes 2% lake area.

Land use classifications and areas (Table 6) were taken from Otonabee River Conservation Authority (1972) for the Indian and Ouse River watersheds. For the smaller watersheds (Bewdley North, Bewdley South, Emily, Dunsford, Martin, Hawkers, Rutherford and McLaren Creeks) land use and areas were digitized from 1:50000 topographic maps.

Rice Lake Water Quality Network

The Otonabee River was the major inflow to Rice Lake. Its nutrient loadings integrated water quality of the Kawartha Lakes upstream and point sources such as the Peterborough STP. Its size and controlled flow precluded a rapid response to hydrological events and so daily sampling was considered adequate during high flow periods. The Ouse and Indian Rivers were the largest of the minor tributaries of Rice

Lake. Both drained agricultural watersheds. Flow of the Indian River was regulated by a dam at Hope Mill and hence high flow events were not sampled as frequently as in unregulated tributaries. The Ouse River and the streams north and south of Bewdley were unregulated and their watersheds primarily agricultural. These were expected to produce rapid increases in flow and nutrient levels during rainstorms and snowmelt. For these reasons, sampling frequency was greatest (up to twice daily during high flow) in these streams. There were about 58 tributary streams to Rice Lake, ranging in size from the Otonabee River to ephemeral streams. Nutrient loadings from minor streams draining ungauged areas were estimated using relationships between watershed area and nutrient loads developed from the two Bewdley streams and the Ouse and Indian Rivers.

The volume of Rice Lake dampened the fluctuations in nutrient loading from tributaries so less frequent sampling sufficed to determine chemistry at the outlet to the Trent River at Hastings. Sampling frequencies are summarized in Table 7.

Total phosphorus and potassium were sampled intensively in Rice Lake during the two weeks of June 1987, corresponding to peak biomass, senescence and death of the P. crispus community. During this period observers on Rice Lake tributaries took daily nutrient samples and daily sampling at the Trent River outflow was continued for two weeks after the die-off.

Water quality was also measured in a small ephemeral stream which discharged to the Otonabee River near Campbelltown during the spring freshet. Although this stream was not part of the routine water quality network it drained several intensive agricultural operations (Figure 4) and it was included to show the potential impacts of agricultural drainage on water quality.

Sturgeon Lake Water Quality Network

The outlet of Cameron Lake at Fenelon Falls was the major inflow to Sturgeon Lake. Flow was relatively steady, regulated, and the drainage area was mostly on the Precambrian Shield. Nutrient load and variability were low at this station, so a low sampling frequency was considered sufficient to estimate nutrient inputs. The Scugog River at Lindsay drained the agricultural watershed of Scugog Lake and so higher nutrient levels were expected. The size of the river, and its regulated flow, made an intermediate sampling frequency sufficient to estimate nutrient loads. Rutherford, Martin, Hawkers, McLaren, Dunsford and Emily Creeks were sampled most frequently (Table 7). All were small and drained agricultural watersheds, producing high and variable nutrient loads. All but Emily Creek, which had a higher proportion of marshland in its watershed, were used to estimate nutrient loadings from the ungauged portion of the Sturgeon Lake drainage. The outlet of Sturgeon Lake (the Big Bob Channel at Bobcaygeon) was sampled at low frequency because of expected lower variations in the lake water chemistry.

Table 7: Flow weighted sampling regime used by local observers at tributary water quality monitoring stations for Rice and Sturgeon Lakes: 1986-1989.

Station Classification	Streamflow Magnitude	Collection Frequency	Annual Sample Total
Class 1	High Flow	2/day	70
(9 stations *)	Medium Flow	2/week	20
	Low Flow	2/month	18
	Annual Total per station		110
Class 2	High Flow	1/day	35
(3 stations **)	Medium Flow	2/week	20
	Low Flow	2/month	18
	Annual Total per station		75
Class 3	High Flow	2/week	20
(3 stations ***)	Medium Flow	1/week	10
	Low Flow	2/month	18
	Annual Total per station		50
Class 4	High Flow	up to 12 /year	
(all 15 stations)			
(by consultant)	Other Flows	1 per month	

* Bewdley North, Bewdley South, Mclaren, Rutherford, Hawkers, Martin, Emily and Dunsford Creeks and the Ouse River.

** Indian, Otonabee and Scugog Rivers.

*** Trent River at Hastings, Big Bob Channel and Fenelon Falls.

Sampling Methodology

Sampling frequency was dependent on the flow of each tributary since peak nutrient loadings and highest variability were expected to coincide with events such as spring runoff or rainstorms. The magnitude of stream flow corresponding to high, medium and low flow events was determined during the early stages of the program and a sampling schedule determined for each tributary. Samples were collected at frequencies ranging from bi-weekly during low flow periods to twice daily during high flow events (Table 7). Staff gauges installed at each hydrological monitoring site were used to estimate flow to determine sampling frequency. Sampling was done year round with only occasional sampling periods missed due to ice conditions.

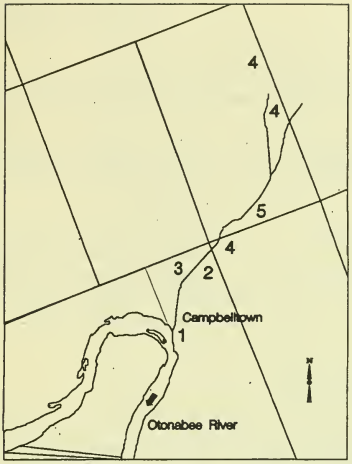

Figure 4: Water quality sampling locations in an ephemeral creek near Campbelltown. (1=mouth, 2=drainage culvert, 3=broiler chicken operation, 4=dairy farms, 5=beef farm)

Non-composite or 'grab' samples were taken from the upper 0.5 m of water, refrigerated, and shipped to the MOE Laboratory within 48 hours. Observers recorded staff gauge readings and other observations of water quality at the time of sample collection. Samples were analyzed for the parameters given in Table 4, according to standard analytical procedures (Wright 1987). Nitrogen to phosphorus ratios were calculated as ((nitrate + Kjeldahl nitrogen)/total phosphorus) and converted to a molar ratio.

Accuracy

The flow-weighted sampling strategy was designed to produce accurate estimates of nutrient flux since the sampling frequency would be proportional to expected variations in water quality that were the result of differences in flow. The accuracy of chemical analysis on individual water samples was well defined by the QA/QC procedures of the analytical labs (Table 4). Accuracy of monthly loading estimates for each tributary could not be precisely defined since it would vary with flow and the response of observers to changes in flow.

RESULTS AND DISCUSSION

Water chemistry measurements are reported in summary tables and figures as part of the text of this report. Detailed results are found in the 6 appendices as follows:

Appendix 1:	Tables of results for each sampling site.
Appendices 2 & 3:	The distribution of concentrations measured for each parameter in a series of frequency histograms for Rice and Sturgeon Lakes respectively.
Appendix 4:	Concentrations of total phosphorus, chloride and potassium plotted against instantaneous discharge for each stream site.
Appendices 5 & 6:	Plots of concentration of various water quality indicators against time for each stream site in the Rice and Sturgeon Lake networks respectively.

Temperature

Rice Lake did not stratify over the course of the study. Except for periods of rapid heating in the early summer and hot windless periods in mid-summer, temperatures differed by less than 2°C for all stations and all depths on any sampling date(Figure 5, Tables 1.1-1.3). Shallow depth and exposure to prevailing winds produced rapid mixing of the water column and rapid heating and cooling of the water mass. Temperature increase was most rapid in May of all years (Figure 5). Summer maximum temperatures were near 24°C in July and August of 1986 and 1987 and near 26°C in August 1988. The maximum recorded range in temperature between surface and bottom (8 m) was 5.0°C in June 1987 at Station 36 (Table 1.2).

Winter temperatures were measured at station 36 on February 28, 1989. On that date they increased from 0.2 °C at the surface to 3.5 °C at the bottom (7m).

Sturgeon Lake was also too shallow and well mixed to stratify. As with Rice Lake, temperatures at all stations and all depths differed by less than 2°C on a given date (Figure 6, Tables1.4-1.6). The maximum range in temperature (6.0°C) was recorded at Station 10 (8 m deep) in April,1986. Maximum summer temperatures were near 24°C in 1986 and 1987, and 26°C in 1988.

Winter temperatures were measured at station 9 on February 28, 1989. On that date they were 0 °C at 1m, 2.4 °C at 4 m and 1.6 °C at 6m (bottom).

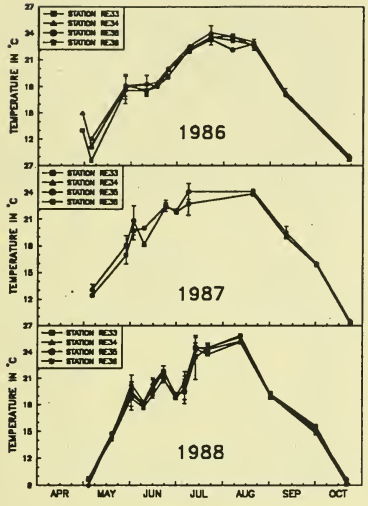

Figure 5: Average temperatures in Rice Lake: 1986 - 1988.

Dissolved Oxygen

Isopleths of dissolved oxygen concentrations in Rice lake are presented in Figure 7. Although periods of low dissolved oxygen concentration were observed in the deeper waters of Rice lake, no significant oxygen stratification occurred. Wind mixing prevented long periods of low oxygen concentrations, even in deeper waters (Figure 7). Dissolved oxygen concentrations of <5.0 mg/L were only recorded at depths > 6.0 m in mid-summer (Fig. 7, Tables 1.1 to 1.3). The lowest concentration of 0.3 mg/L was recorded at the 8m depth at Station 36 in July of 1988. These patterns of wind mixing and low oxygen content at depth suggest that oxygen demand was sufficiently high to have produced extended periods of anoxia if Rice Lake were deeper and not as well mixed.

Some oxygen demand was present under the ice of Rice Lake but no anoxia was recorded. On February 28, 1989, dissolved oxygen concentrations decreased from 14.5 mg/L at the surface to 7 mg/L at the 7m depth (bottom) of Station 36.

Sturgeon Lake also showed no significant oxygen stratification and only occasional periods of low concentration. At all stations but the deepest (Station 9, 10m) dissolved oxygen concentrations always exceeded 4 mg/L and values below 5 mg/L were extremely rare (Tables 1.4 to 1.6). At Station 9, minimum dissolved oxygen

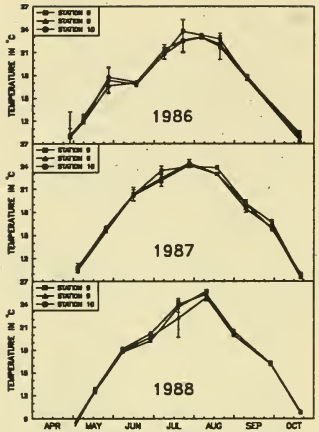

Figure 6a: Average temperatures in Sturgeon Lake stations 6, 9 and 10. (Mean+/-1SD,all depths)

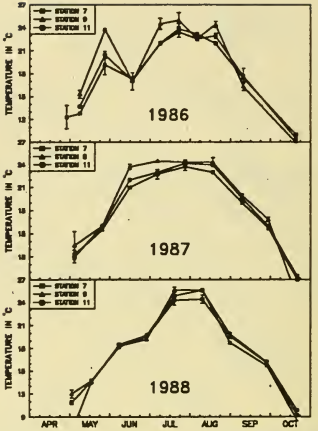

Figure 6b: Average temperatures in Sturgeon Lake stations 7, 8 and 11.

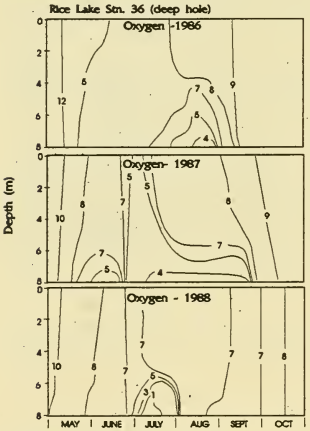

Figure 7: Dissolved oxygen isopleths in Rice Lake

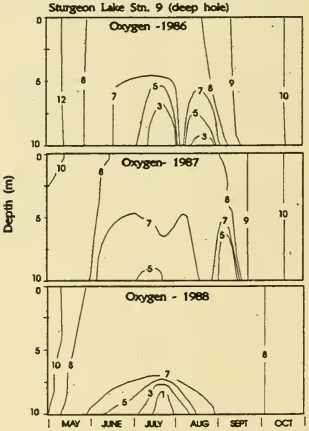

Figure 8: Dissolved oxygen isopleths in Sturgeon Lake

concentrations of 2.5, 4.5 and 0.1 mg/L were recorded in 1986, 1987 and 1988 respectively. Mid-summer values were <3 mg/L at depths below 7m in 1986 and 1988 and <5.0 mg/L in 1987 (Figure 8). On July 19, 1988 stratification was apparent at Station 9. Dissolved oxygen concentrations were <0.7 mg/L below 6m and >5.0 mg/l in shallower water. This stratification was temporary; measurements made in August showed that oxygen at the bottom had increased to >3.0 mg/L (Figure 9).

Winter measurements at Station 9 showed some oxygen demand, but no anoxia. Surface concentration was 13.4 mg/L on February 28, 1989. Dissolved oxygen decreased to 8.0 mg/L at the 6m depth (bottom).

Rice Lake Water Chemistry

Water chemistry statistics for all Rice Lake stations are presented in Table 8. Data for individual stations are given in Tables 1.7 to 1.10 (App. 1) and on Figures 2.1B to 2.9B (Appendix 2).

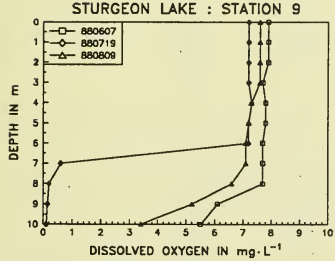

Figure 9: Sturgeon Lake oxygen profiles showing temporary stratification at station 9, in the summer of 1988.

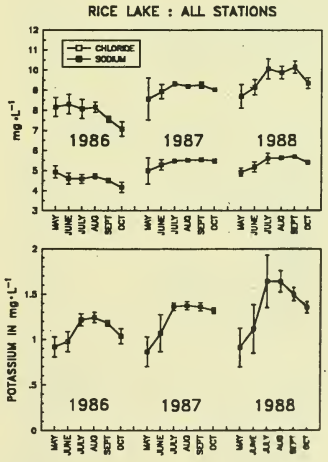

Figure 10: Concentrations of chloride (upper line), sodium(lower line), and potassium in Rice Lake.

Concentrations of sodium and chloride in Rice Lake increased significantly over the course of the study. Chloride at all stations averaged 8.0 ± 0.58, 9.0 ± 0.51 and 9.4 ± 0.69 mg· L^{-1} in 1986, 1987 and 1988 respectively and all between-year differences were significant. Concentrations were highest in mid-summer (July-September) of 1987 and 1988 (Table 9, Fig 10) compared to high values in May - June of 1986. Summer

Table 8: Water quality statistics for all stations in Rice Lake : 1986-1988.

	TP ($\mu g \cdot L^{-1}$)	Chl a ($\mu g.L^{-1}$)	TKN ($\mu g.L^{-1}$)	Cond ($\mu S.cm^{-1}$)
Mean	29	15.7	642	221
Std. Deviation	13	16.7	231	17
Minimum	5	0.1	290	167
Maximum	84	99.0	1590	288
Median	25	9.4	560	223
First/Third Quartiles	19/36	5.9/19.0	490/750	211/232
Number of Samples	162	156	162	163

	NH_4 ($\mu g.L^{-1}$)	NO_2 ($\mu g.L^{-1}$)	NO_3 ($\mu g.L^{-1}$)
Mean	74	6.0	97
Std. Deviation	55	5.0	522
Minimum	2	1.0	5
Maximum	332	32.0	6590
Median	60	5.0	25
First/Third Quartiles	40/92	3.0/7.0	20/58
Number of Samples	163	163	162

	Na ($mg \cdot L^{-1}$)	Cl ($mg \cdot L^{-1}$)	K ($mg.L^{-1}$)
Mean	5.12	8.87	1.19
Std. Deviation	0.49	0.90	0.29
Minimum	3.80	0.90	0.57
Maximum	6.60	6.65	2.47
Median	5.22	9.00	1.21
First/Third Quartiles	4.71/5.50	8.2/9.4	0.99/1.37
Number of Samples	162	163	163

Table 9: Monthly and annual mean concentrations of chloride and sodium in Rice Lake.

	Chloride			Sodium			
Yr/Mo	x̄	SD	n		x̄	SD	n
1986							
May	8.16[a]	0.47	8	May	4.93[c]	0.30	8
Jun	8.30[b]	0.48	12	Jun	4.61[a]	0.27	12
Jul	8.07[a]	0.47	8	Jul	4.59[a]	0.22	8
Aug	8.16[a]	0.27	8	Aug	4.72[ac]	0.13	8
Sep	7.07[d]	0.35	4	Sep	4.51[a]	0.11	4
Oct	7.56[d]	0.14	7	Oct	4.17[d]	0.26	7
1987							
May	8.57[abc]	1.04	8	May	4.99[c]	0.66	8
Jun	8.93[c]	0.35	20	Jun	5.29[b]	0.25	19
Jul	9.32[c]	0.04	8	Jul	5.48[b]	0.04	8
Aug	9.20[c]	0.07	4	Aug	5.52[b]	0.05	4
Sep	9.26[c]	0.17	8	Sep	5.54[b]	0.04	8
Oct	9.03[c]	0.05	4	Oct	5.48[b]	0.11	4
1988							
May	8.69[c]	0.59	12	May	4.92[c]	0.19	12
Jun	9.15[c]	0.37	16	Jun	5.18[bc]	0.24	16
Jul	10.07[e]	0.50	13	Jul	5.61[e]	0.25	13
Aug	9.88[e]	0.31	8	Aug	5.64[e]	0.09	8
Sep	10.15[e]	0.30	4	Sep	5.71[e]	0.09	4
Oct	9.35[c]	0.26	4	Oct	5.41[e]	0.04	4

Identical superscripts within a column denote no significant differences in mean values ($p < 0.05$). All concentrations given in $mg \cdot L^{-1}$.

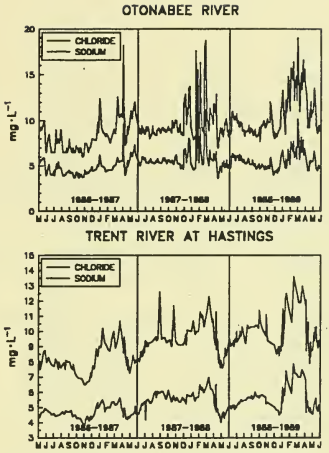
OTONABEE RIVER
CHLORIDE
SODIUM
mg·L⁻¹
1986–1987
1987–1988
1988–1989
M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J
TRENT RIVER AT HASTINGS
CHLORIDE
SODIUM
mg·L⁻¹
1986–1987
1987–1988
1988–1989
M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J

Figure 11: Concentrations of sodium(lower line) and chloride(upper line) measured in the Otonabee and Trent Rivers

precipitation was greatest in 1986. Sodium concentrations were significantly lower (4.60 ± 0.32 $mg \cdot L^{-1}$) in 1986 compared to 1987-1988 (mean = 5.34 ± 0.35 $mg \cdot L^{-1}$). These patterns were also clear at the Trent River outflow and Otonabee River inflow to Rice Lake (Figure 11). Concentrations of chloride and sodium increased at each site in each year of the study, and all but the 1987-1988 increases were significant ($P < 0.05$).

Increased chloride concentrations in Rice Lake are also clear in data collected in 1972 (see discussion below). Mean chloride concentrations for June, August and September were 6.0, 6.1 and 6.3 $mg.L^{-1}$ in 1972. Between 1986 and 1988 however, these values had risen to 8.8, 9.1 and 9.1 $mg.L^{-1}$ for the same three months (Table

Table 10: Changes in chloride in Rice Lake between 1972 and 1986-1988.

Year	1972			1986			1987			1988			1986-1988		
	x̄	SD	n	x̄	SD	n	x̄	SD	n	x̄	SD	n	x̄	SD	n
All Data	6.1	0.3	28	8.1*	0.5	24	9.0*	0.3	32	9.5	0.5	28	8.9*	0.7	84
Jun.	6.0	0.0	8	8.3*	0.5	12	8.9*	0.3	20	9.2*	0.4	16	8.8*	0.5	48
Aug.	6.1	0.3	12	8.2*	0.3	8	9.2*	0.1	4	9.9*	0.3	8	9.1*	0.8	20
Sept.	6.3	0.5	8	7.6*	0.1	4	9.3*	0.2	8	10.2*	0.3	4	9.1*	1.0	16

Asterisks within a row denote significant differences between years ($p < 0.05$). No between station differences were significant. All concentrations are in $mg \cdot L^{-1}$.

Table 11: Monthly and annual mean concentrations of potassium, Kjeldahl nitrogen and ammonia nitrogen in Rice Lake, 1986-1988.

			Potassium		TKN		Ammonia	
Year	Mo.	n	Mean	SD	Mean	SD	Mean	SD
1986	May	8	0.92^{A}	0.11	501^{AB}	706	54.5^{A}	10.0
	Jun	12	0.98^{A}	0.11	461^{AB}	29.4	46.0^{A}	20.6
	Jul	8	1.22^{B}	0.07	543^{AB}	84.8	28.3^{A}	26.0
	Aug	8	1.24^{B}	0.06	790^{B}	72.3	130.3^{BC}	44.7
	Sep	4	1.18^{B}	0.03	620^{AB}	134	159.5^{C}	76.9
	Oct	7	1.04^{A}	0.08	616^{AB}	70	72.6^{A}	39.6
1987	May	8	0.86^{A}	0.16	430^{A}	75.2	41.8^{A}	34.4
	Jun	20	1.07^{A}	0.21	429^{A}	80.2	63.7^{A}	21.9
	Jul	8	1.37^{B}	0.04	518^{AB}	129.4	34.0^{A}	17.1
	Aug	4	1.38^{B}	0.05	953^{B}	59.1	73.0^{A}	22.9
	Sep	8	1.36^{B}	0.05	1015^{C}	106.9	71.8^{A}	24.7
	Oct	4	1.32^{B}	0.03	783^{B}	88.8	99.0^{AB}	46.5
1988	May	12	0.91^{A}	0.21	673^{AB}	157	51.8^{A}	25.2
	Jun	16	1.12^{A}	0.27	616^{AB}	100.5	59.4^{A}	30.2
	Jul	13	1.64^{C}	0.29	618^{AB}	311.9	48.6^{A}	31.3
	Aug	8	1.64^{C}	0.12	1068^{C}	179.5	192.5^{C}	88.5
	Sep	4	1.50^{BC}	0.07	1043^{C}	94.3	190.0^{C}	23.0
	Oct	4	1.36^{B}	0.06	765^{AB}	89.6	19.0^{B}	9.6

Identical superscripts within a column denote no significant differences in mean values ($p < 0.05$). Potassium concentrations given in $mg \cdot L^{-1}$, all others in $\mu g \cdot L^{-1}$.

10). The rate of change between 1986 and 1988 was greater than that observed between 1972 and 1986, suggesting either increased inputs of chloride in the 1980s or differences in hydrology (ie. dry summers in 1987 and 1988) between the two periods.

Potassium concentrations in Rice Lake showed a strong seasonal pattern but no between-year differences. Concentrations rose from low values (0.86-0.92 $mg \cdot L^{-1}$) in May to significantly higher values in July, August and September. The peak of 1.24-1.64 $mg \cdot L^{-1}$ was seen in August of each year of the study (Table 11, Figure 10). Concentrations were significantly higher in the summer of 1988 compared to 1986 and 1987. These patterns are discussed later.

Concentrations of Kjeldahl nitrogen peaked in August and September of each year coinciding with chlorophyll maxima (Table 11, Figure 12). Spring values of 430-673 $\mu g \cdot L^{-1}$ were about half those of late summer (1015-1068 $\mu g \cdot L^{-1}$). Ammonia concentrations followed similar patterns, increasing 2-3 fold between May and August-September. Maxima in 1987 (72 $\mu g \cdot L^{-1}$, Table 11) were about half those in 1986 (130-160 $\mu g \cdot L^{-1}$) or 1988 (191 $\mu g \cdot L^{-1}$).

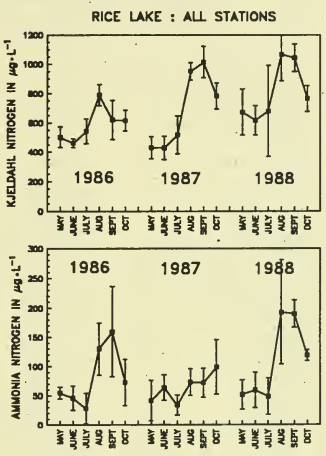

Figure 12: Kjeldahl and ammonia nitrogen concentrations in Rice Lake between May and October

Between station differences in chloride, sodium, potassium, or Kjeldahl or ammonia nitrogen were not significant.

Rice Lake: Trophic Status Indicators

Total phosphorus concentrations in Rice Lake were the only trophic status indicator that showed significant between-station differences (Table 12). They declined from west to east in Rice Lake, but the only significant difference was between TP concentration of Station 33, near Bewdley (33.4 ± 17.4 $\mu g \cdot L^{-1}$) and at Station 36 near the outlet (25.7 ± 8.6 $\mu g \cdot L^{-1}$, see Table 13). Concentrations of TP in Rice Lake peaked in late summer. Highest TP concentrations were recorded in August in 1986 (39.1 $\mu g \cdot L^{-1}$), September in 1987 (50.1 $\mu g \cdot L^{-1}$), and September in 1988 (50.0 $\mu g \cdot L^{-1}$, Figure 13). Total chlorophyll *a* concentrations followed a similar pattern, peaking at 33.9, 57.0

Table 12: Analysis of variance (ANOVA) for comparison of trophic status indicators in Rice Lake between years, station and months.

Source	SS	Df	MS	F-Ratio	P(F)
A) Chlorophyll a (Corrected)					
Grand Mean	29396	1	29396	388.7	0.000
Month	18471	5	3694	48.85	0.000
Year	1764	2	882.5	11.67	0.000
Year.Month	1913	10	191.3	2.530	0.011
Stn.	52.25	3	17.41	0.230	0.875
Stn.Month	553.6	15	36.91	0.488	0.939
Stn.Year	433.5	6	72.26	0.955	0.461
Stn.Year.Mo	1489	30	49.64	0.656	0.900
Error	5671	75	75.61		
B) Chlorophyll a (Total)					
Grand Mean	46309	1	46309	458.7	0.000
Month	26592	5	5318.4	52.68	0.000
Year	2022.7	2	1011.3	10.01	0.000
Year.Month	2861	10	286.10	2.834	0.004
Stn	52.317	3	17.439	0.172	0.914
Stn.Month	731.86	15	48.790	0.483	0.942
Stn.Year	573.50	6	95.583	0.946	0.466
Stn.Year.Mo	2058	30	68.600	0.679	0.881
Error	8076	80	100.95		
C) Total Phosphorus					
Grand Mean	120063	1	120063	977.4	0.000
Month	8451.0	5	1690.2	13.75	0.000
Year	1248.9	2	624.48	5.083	0.008
Year.Month	2439.6	10	243.86	1.985	0.045
Stn	1446.1	3	482.03	3.924	0.011
Stn.Month	1236.7	15	82.447	0.671	0.806
Stn.Year	381.86	6	63.643	0.518	0.793
Stn.Year.Mo	798.51	30	26.617	0.216	1.000
Error	10564	86	122.83		
D) Secchi Depth					
Grand Mean	358.7	1	358.73	496.4	0.000
Month	58.82	5	11.764	16.28	0.000
Year	0.180	2	0.0903	1.125	0.883
Year.Month	6.792	10	0.6792	0.940	0.502
Stn	1.161	3	0.3872	0.535	0.659
Stn.Month	3.242	15	0.2161	0.299	0.994
Stn.Year	0.135	6	0.0226	0.031	0.999
Stn.Year.Mo	3.399	30	0.1133	0.156	1.000
Error	52.02	72	0.7225		

Differences were judged significant at $p < 0.05$.

Table 13: Mean values for Rice Lake trophic status indicators 1986-1988. Identical superscripts within a column denote comparisons which were not significantly different ($p < 0.05$).

	Chlorophyll a (Corrected)			Chlorophyll a (Total)			Total Phosphorus			Secchi Depth		
	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n
May	8.9^{D}	4.8	5	11.3^{D}	5.3	5	23.6^{B}	6.7	9	2.4^{A}	0.88	28
Jun	3.6^{C}	1.2	12	5.4^{C}	1.8	12	23.2^{B}	6.0	12	2.5^{A}	0.96	44
Jul	6.1^{C}	2.6	8	8.0^{C}	3.2	8	29.6^{AB}	7.1	7	2.1^{AB}	0.47	20
Aug	29.1^{B}	10.5	7	33.9^{B}	12.0	8	39.1^{A}	9.7	8	0.9^{C}	0.23	20
Sep	13.3^{D}	3.2	5	16.5^{D}	3.6	5	24.4^{B}	9.1	5	0.8^{C}	0.32	16
Oct	8.2^{D}	5.2	7	10.3^{D}	6.1	7	19.3^{B}	6.8	7	1.8^{B}	0.34	16
1986	10.5	9.9	44	13.6	11.7	45	26.4	9.5	48	**All Yrs** 1.94	0.34	144
May	4.0^{C}	3.2	8	5.5^{C}	3.9	8	19.0^{B}	5.2	8			
Jun	5.2^{C}	4.3	20	7.2^{C}	5.7	20	28.2^{B}	17.7	20			
Jul	9.7^{D}	3.1	8	13.7^{D}	4.8	8	27.8^{B}	10.9	8			
Aug	45.1^{A}	4.1	4	57.0^{A}	5.7	4	47.5^{A}	9.0	4	NSD between years		
Sep	18.3^{E}	2.6	4	20.3^{E}	7.7	8	50.1^{A}	15.5	8			
Oct	14.8^{E}	1.3	4	19.7^{E}	1.4	4	27.3^{B}	4.8	4			
1987	11.0	11.8	48	14.7	14.5	52	31.5	16.8	52			
May	10.6^{D}	6.4	11	12.4^{D}	7.7	11	23.8^{B}	4.8	12			
Jun	5.7^{C}	4.2	16	7.2^{C}	4.7	16	25.9^{B}	11.3	16			
Jul	8.3^{D}	2.6	12	9.8^{D}	2.8	12	23.9^{B}	5.2	14			
Aug	50.3^{A}	27.6	8	56.5^{A}	31.2	8	44.4^{A}	9.0	8			
Sep	32.8^{B}	12.2	4	38.0^{B}	13.5	4	50.0^{A}	5.4	4			
Oct	17.3^{E}	8.3	4	21.3^{E}	9.0	4	33.3^{A}	3.9	4			
1988	16.5	19.2	55	19.2	21.5	55	29.7	11.7	58			
NSD between stations							Stn					
							33	33.4^{A}	17.4	39		
							34	29.8^{AB}	12.3	38	NSD between stations	
							35	28.6^{AB}	12.2	40		
							36	25.7^{B}	8.6	41		

and 56.5 $\mu g \cdot L^{-1}$ in August of 1986, 1987 and 1988 respectively (Figure 13). Early summer concentrations of total chlorophyll a were 5.4-12.4 $\mu g \cdot L^{-1}$ in May and June of the three years studied. No significant differences in chlorophyll a concentration were observed between stations on Rice Lake (Table 13).

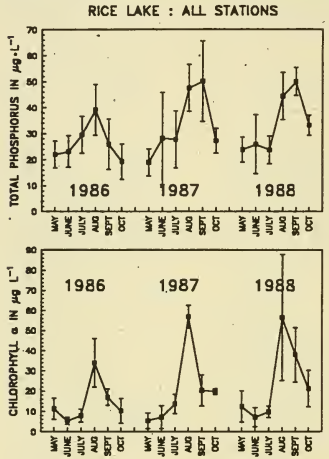

Figure 13: Total phosphorus and chlorophyll a concentrations in Rice Lake between May and October

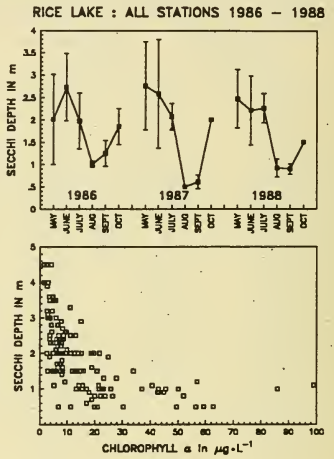

Figure 14: Secchi depth and chlorophyll a concentrations in Rice Lake

Secchi depths were different from month to month, but not between stations or years (Tables 12 and 13). Secchi depths averaged 2.4-2.5 m in May and June, declined to 0.8 by September and had increased to 1.8 m by October (Figure 14). Although the Secchi depth/chlorophyll relationship showed a great deal of scatter, it demonstrated that water clarity was controlled by phytoplankton densities in Rice lake.

Mean monthly values of the N:P ratio recorded at the outflow to Rice Lake ranged from 87:1 to 950:1 when calculated on a molar basis (Table 21) showing that Rice Lake was phosphorus limited (Hutchinson 1957). There was a significant but weak relationship between total phosphorus and chlorophyll a at the four stations during the summer months. Much scatter was evident in the relationships whether for total chlorophyll a ($r^2 = 0.55$, Figure 15) or for corrected chlorophyll a ($r^2=0.52$) . Including obvious outliers from June 2 and September 10, 1987 further weakened the relationship. The relationship was not improved by logarithmic transformation.

Suppression of algal growth by self-shading or grazing of algae by zooplankton may have contributed to the observed scatter. The outliers of Sept 10 1987 may also reflect a blue-green algal bloom and resultant presence of non-chlorophyll pigments such as phaeophytins.

Table 14: Trophic status indicators for Rice Lake from 1972 surveys.

(a) All Stations Combined

	Secchi Depth			Chlorophyll *a*			Total Phosphorus			TKN		
	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n
Jun.	1.75^{A}	0.26	20	10.26^{A}	4.16	20	43.6^{A}	10.8	8	521^{A}	37	8
Aug.	0.92^{B}	0.20	20	20.44^{B}	14.27	20	71.0^{B}	22.6	12	813^{B}	159	12
Sept	1.08^{C}	0.22	20	3.24^{C}	1.16	20	72.0^{B}	7.1	8	768^{B}	130	8

No between station differences were significant. Identical superscripts denote no significant difference between means ($p < 0.05$). All concentrations in $\mu g \cdot L^{-1}$.

(b) Two stations showing inferred change in algal community in late summer

	Stn. 33				Stn 35			
	TP	Chl a	Secchi	Phyto	TP	Chl a	Secchi	Phyto
June 21	31	2.2	2.0	5.1	43	2.3	2.5	4.0
July 12	59	16	2.3	4.1	21	6.4	2.0	5.2
Aug 1	83	13	1.0	26.3	52	27	1.5	5.5
Aug 23					80	17	1.3	7.8
Sept 13	79	1.3	1.4	24.8	51	2.3	1.2	29.1
Sept 20	92	4.2	1.4	4.7	85	6.2	1.4	3.8

TP & chlorophyll *a* concentrations in $\mu g \cdot L^{-1}$. Secchi depth in m and phytoplankton as biovolume (mg/m^3)

Rice Lake Historical Trophic Status Comparison

Three 5-day surveys of water quality at 4 sites in Rice Lake were carried out by MOE 'Recreational Lakes' staff in June, August and September of 1972. Concentrations of total phosphorus rose from 43.6 $\mu g.L^{-1}$ in June (4 station average, Table 14 a) to 71 and 72 $\mu g.L^{-1}$ in August and September. Kjeldahl nitrogen concentration rose from 521 $\mu g.L^{-1}$ in June to 813 and 768 $\mu g.L^{-1}$ in August and September, respectively. Chlorophyll a rose from 10.3 $\mu g.L^{-1}$ in June to 20.4 $\mu g.L^{-1}$ in August, with a corresponding decrease in Secchi depth from 1.75 to 0.92m (Table 14).

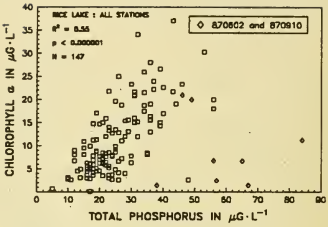

Figure 15: Relationship between phosphorus and chlorophyll a concentrations in Rice Lake, May - October 1986-1988.

The low concentration of chlorophyll in September (3.2 $\mu g.L^{-1}$) likely reflects a shift in dominance within the algal community since TP concentrations did not change and Secchi depth showed only a minor increase. (Table 14 a). Phytoplankton biovolume estimates were available for two of the stations and they either increased (Stn.35, Table 14b) or did not change (Stn. 33) between August and mid- September when chlorophyll decreased by 80-90%. This pattern suggests that the algal community shifted to blue-green dominance. Blue-green algae would be recorded as phytoplankton biovolume but not as chlorophyll a because of the dominance of phaeopigments in these species.

Historical comparisons were based only on June, August and September measurements. The exact correspondence between sampling locations in 1972 and 1986-1988 was not known. Between-station differences within a year were either insignificant (1972) or minor (1986-1988) and hence data from all stations were pooled for between-year comparisons.

The water clarity of Rice Lake improved from 1.25 to 1.75 m between 1972 and 1986-1988 . Individual differences for 1986 and 1987 were significant (Table 15). The improvement was confined to June only, as comparisons for August and September were not significant between 1972 and 1986-1988.

Table 15: Changes in Secchi depth in Rice Lake between 1972 and 1986-88.

	1972			1986-1988		
	Mean	SD	n	Mean	SD	n
All Data	1.25	0.43	60	1.75*	0.79	80
Jun.	1.75	0.26	20	2.49*	0.96	44
Aug.	0.92	0.20	20	0.87	0.23	20
Sept.	1.08	0.22	20	0.84	0.32	16

Asterisks within a row denote significant differences between years and months ($p < 0.05$). No between station differences were significant. All depths given in m.

Changes in water clarity were not directly attributable to changes in TP and chlorophyll a. June, August and September concentrations of TP also decreased by 40% between 1972 and 1986-1988 (Table 16). Small decreases in June chlorophyll a concentrations were not significant and August-September concentrations of chlorophyll a (Table 17) and total Kjeldahl nitrogen (Table 18) rose significantly between 1972 and 1986-1988. Changes in these indicators do not show a clear change in trophic status of Rice Lake over 15 years although TP measurements suggest improved water quality. The increase in chlorophyll a could, however, be interpreted as an improvement in water quality if the 1972 pattern of late-summer blue green dominance is considered. Increases in chlorophyll a between 1972 and the present, accompanied by decreased TP and increased water clarity especially in August and September may reflect decreased dominance by blue green algae in late summer and an increase in green algae and diatoms. A change to a more diverse algal community could cause a shift from phaeophytins to chlorophyll with increased water clarity. These patterns may also reflect changes in the macrophyte community, changes in trophic interactions, or differences in analytical methodology.

All comparisons between present and past TP concentrations must be interpreted with caution. In 1972, the detection limit for TP in the MOE analytical laboratory was 7 $\mu g.L^{-1}$ (MOE, Lab Services Branch, 1975) but the routine limit may have been higher. In addition precision of analysis ranged from +/- 6-11 $\mu g.L^{-1}$. Present day analyses have a detection limit of 2 $\mu g.L^{-1}$ and a coefficient of variation of 24.4% (Table 4). Nevertheless, the decline in mean, late-summer TP concentration from 71-72 $\mu g.L^{-1}$ in 1972 (Table14) to 39-50 $\mu g.L^{-1}$ in 1986-88 (Table 13) exceeds the change in analytical error and likely reflects a true drop in concentration.

Molar ratios of total nitrogen to TP were 30:1 and 33:1 in 1972 and 1976 (MOE/MNR 1976). Mean monthly N:P ratios ranged from 87:1 to 950:1 over the course of the present study. This suggests that the degree of phosphorus limitation has increased over the intervening 10 years further substantiating the apparent drop in TP and shift away from blue-green dominance in the late summer algal community.

Table 16: Changes in phosphorus concentration in Rice Lake between 1972 and 1986-88.

	1972			1986			1987			1988			1986-1988		
	Mean	**SD**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**
All Data	63.5	20.4	28	**29.0**	10.6	24	**36.1**	19.0	32	**34.6**	14.3	28	**33.6**	15.5	84
Jun.	43.6	10.8	8	**23.2**	6.0	12	**28.2**	17.7	20	**25.9**	11.3	16	**26.2**	13.4	48
Aug.	71.0	22.6	12	**39.1**	9.7	8	**47.5**	9.0	4	**44.4**	9.0	8	**42.9**	9.4	20
Sept.	72.0	7.1	8	**26.0**	9.7	4	**50.1**	15.5	8	**50.0**	5.4	4	**44.1**	15.9	16

Table 17: Changes in chlorophyll a concentration in Rice Lake between 1972 and 1986-88.

	1972			1986			1987			1988			1986-1988		
	Mean	**SD**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**
All Data	11.3	11.1	60	16.8	14.8	24	16.7	17.6	32	**25.7**	28.1	28	**19.7**	21.2	84
Jun.	10.3	4.2	20	5.4	1.8	12	7.2	5.7	20	7.2	4.7	16	6.7	4.6	48
Aug.	20.4	14.3	20	**33.9**	12.0	8	**57.0**	5.7	4	**56.5**	31.2	8	**47.6**	23.4	20
Sept.	3.2	1.2	20	**17.0**	4.0	4	**20.3**	7.7	8	**38.0**	13.5	4	**23.9**	11.9	16

Table 18: Changes in Kjeldahl nitrogen concentration in Rice Lake between 1972 and 1986-88.

	1972			1986			1987			1988			1986-1988		
	Mean	**SD**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**
All Data	716	177	28	597	165	24	641	291	32	806	255	28	683	261	84
Jun.	521	37	8	461	29	12	429	80	20	616	100	16	499	115	48
Aug.	813	159	12	790	72	8	**953**	59	4	**1068**	180	8	**934**	175	20
Sep.	768	130	8	**620**	134	4	**1015**	107	8	**1043**	94	4	**923**	209	16

Bold case within a row denote significant differences between 1972 and present ($p < 0.05$). No between station differences were significant. All concentrations are in $\mu g \cdot L^{-1}$.

Rice Lake Tributary Network

A summary of water quality statistics for all streams in the Rice lake tributary network is presented in Table 19. Detailed statistics for individual streams are given in Tables 1.11 to 1.16 (App. 1). Histograms showing the frequency of various concentrations measured for each water quality parameter in each stream are presented in Figures 2.1A to 2.9A (App. 2). Figures 4.1 to 4.6 (App. 4) relate discharge to measured concentrations of phosphorus, potassium and chloride in each stream. Figures 5.1 to 5.25 plot the concentrations of total phosphorus, chloride, potassium, nitrogen forms and chlorophyll a against time for the three year study.

Total Phosphorus

Four patterns of phosphorus concentration were observed among the 6 Rice Lake tributary streams. The Bewdley South stream showed the highest average concentrations and more frequent extremes in total phosphorus. These extremes in response were also observed for discharge (Hutchinson et al. 1993a). More than 30% of the 328 measurements made over three years exceeded 100 $\mu g.L^{-1}$ (Fig 2.1A) and high values of 2.9 and 3.15 $mg.L^{-1}$ were recorded in March of 1986. The median concentration over three years was 46 $\mu g.L^{-1}$ (Table 19).

The Bewdley North stream and the Ouse River were neither as enriched nor did they show the extremes in TP concentrations as observed in the Bewdley South stream. Less than 5% of the TP measurements exceeded 100 $\mu g.L^{-1}$ (Figure 2.1A) and the highest values recorded were 310 and 173 $\mu g.L^{-1}$. The median phosphorus concentrations at Bewdley North and the Ouse River were 36 and 27 $\mu g.L^{-1}$, respectively (Table 19).

Total phosphorus concentrations in the Indian and Otonabee Rivers were lower than those in the smaller streams. Less than 5% of the total phosphorus concentrations exceeded 100 $\mu g.L^{-1}$ and more than 80% were between 10 and 40 $\mu g.L^{-1}$ (Figure 2.1A). The Indian River had the lower phosphorus concentrations of the two ; many TP concentrations were $<10ug.L^{-1}$. Maximum concentrations were 307 and 290 $\mu g.L^{-1}$ for the Indian and Otonabee Rivers and median values were 18 and 24 (Table 19).

Phosphorus concentrations at the Trent River outlet from Rice Lake showed the influence of the lake in damping variable inputs of phosphorus. The highest concentration recorded was only 83 $\mu g.L^{-1}$, 75% of all values were 10-30 $\mu g.L^{-1}$ and the median concentration was 20$\mu g.L^{-1}$ (Figure 2.1A, Table 19). Lower values were recorded at the Trent River site than at in-lake sites (Figure 2.1B, Table 8). This reflects both phosphorus retention in Rice Lake and year-round sampling at the Trent River site compared to sampling only the May to October period in the lake when phosphorus concentrations were higher.

Table 19: Water quality summary for all Rice Lake tributary streams

	TP				NH_4				TKN				NO_3			
	n	$\bar{x}$	SD	med.	n	$\bar{x}$	SD	med.	n	$\bar{x}$	SD	med.	n	$\bar{x}$	SD	med.
Bewdley North	322	44	34	36	330	39	50	28	327	291	161	120	330	837	363	800
Bewdley South	328	158	349	46	330	172	368	22	329	677	1041	270	330	1986	572	1960
Indian R.	506	26	35	18	513	57	87	30	509	523	249	460	513	166	194	85
Ouse R.	309	30	21	27	310	59	79	42	313	559	198	520	310	499	256	465
Otonabee R.	438	29	26	24	444	101	63	86	442	533	160	500	444	185	128	175
Trent R.	368	22	9	20	370	72	45	62	371	550	166	510	371	122	111	85

	Na				Cl				K			
	n	$\bar{x}$	SD	med.	n	$\bar{x}$	SD	med.	n	$\bar{x}$	SD	med.
Bewdley North	297	5.2	2.8	4.6	329	5.9	4.3	5.3	201	0.94	0.36	0.88
Bewdley South	292	4.5	1.1	4.3	329	6.6	3.3	5.8	194	2.3	1.4	1.70
Indian R.	511	4.4	1.3	4.0	512	8.9	2.7	8.3	447	1.3	0.5	1.2
Ouse R.	308	6.3	3.0	5.3	306	13.2	6.1	11.2	250	1.4	0.6	1.2
Otonabee R.	442	5.4	1.1	5.3	444	9.5	2.2	9.1	405	1.2	0.2	1.2
Trent R.	366	5.1	0.7	5.0	365	9.1	1.2	9.0	322	1.2	0.2	1.2

All concentrations in $\mu g.L^{-1}$ except Na; Cl and K ($mg.L^{-1}$). n= number of samples, $\bar{x}$=arithmetic mean, SD= 1 standard deviation, med=med

Figures 3.1 to 3.6 show attempts to quantify relationships between instantaneous measurements of stream discharge and TP concentration. No relationships were apparent in the two Bewdley streams; many high TP concentrations were measured across the entire range of flows in each (Figures 4.1, 4.2). The remaining tributaries showed strong tendencies towards lower TP concentrations at higher flows. In the Indian River 25 of 29 concentrations >50 $\mu g.L^{-1}$ were measured in the lower 25% of flows (Fig.4.3). In the Ouse River, 18 of 19 TP concentrations >50 $\mu g.L^{-1}$ were measured in the lower 25% of flows (Figure 4.4).

The concentration/discharge pattern for the Otonabee River suggests that the river dilutes a constant input of phosphorus. One source of this could be the Peterborough STP. Twenty five of the twenty six TP measurements over 50 $\mu g.L^{-1}$ were made at flows of less than 180 $m^3.s^{-1}$. Only one concentration >50 $\mu g.L^{-1}$ was measured at higher flows (Fig 4.5). The Trent River at Hastings site showed a similar pattern; 15 of 18 TP concentrations >40 $\mu g.L^{-1}$ occurred at flows of <50 $m^3.s^{-1}$, or the lower 10% of flow. All measurements exceeded 10 $\mu g.L^{-1}$ at flows above 150 $m^3.s^{-1}$ (Figure 4.6).

The highest concentrations of TP in the Bewdley North and Bewdley South streams were recorded during the spring freshet of each study year. The March 1988 freshet produced higher concentrations than in 1987 or 1989 (Figure 5.1, 5.2). High values recorded in mid to late summer were likely a result of rainfall after prolonged dry

spells. Fertilizer applications to crops or runoff of livestock wastes within the watersheds may also have contributed to these increases. No increase in phosphorus concentration was seen during the wet autumn period.

The Indian River also had its highest TP concentrations during the spring freshet (Figure 5.3). High concentrations were seen at high flows as well as low flows (Figure 4.3). High concentrations between May and July 1986 likely reflected a wet spring. Scattered high concentrations during other periods are likely responses to rain events after prolonged dry spells or to releases of water from the Hope Mill dam.

Although increased TP concentrations accompanied increased springtime flow of the Ouse River, concentrations in July and August frequently matched or even exceeded (1986-87) spring freshet values (Figure 5.4). In all years, the high summertime concentrations declined with the onset of autumn rains, reaching minimum levels in October and November. This pattern may reflect a steady TP load where concentrations vary as a result of flow or agricultural activities such as fertilizer applications within the watershed.

The seasonal pattern of TP concentration in the Otonabee River was similar to that in the Ouse with peak concentrations in the spring and the summer (Figure 5.5). The steady point source of phosphorus from the Peterborough STP may produce peaks during low summer flow. Figure 4.5 suggests dilution of a point source such that high concentrations are more frequent at low flows.

The seasonal pattern of TP concentration at the Trent River reflects the damping of the springtime peaks in watershed load by the volume of Rice Lake. Maximum TP concentrations were recorded in August and September of all years (Figure 5.6). The seasonal trends in phosphorus concentration tracked those of chlorophyll a very closely (Figure 5.25). The source of the gradual increase in TP concentration in Rice Lake over the summer is not clear. It may reflect the gradual release of phosphorus from lake sediments following the June collapse of P. crispus, phosphorus from late summer blue-green algal blooms moving out of the lake, or the lower summer flow into Rice Lake and resultant concentration of phosphorus entering the lake from point sources and agricultural land within the watershed. These possibilities will be examined further in the report on nutrient budgets (Hutchinson et al. 1993c)

Chloride

The Bewdley North and Bewdley South streams showed similar distributions of chloride concentration (Figure 2.2A). Nearly 80% of the chloride measurements made in each stream were between 2 and 8 $mg.L^{-1}$ and < 3% were above 20 $mg.L^{-1}$. Median values for Bewdley North and Bewdley South were 5.3 and 5.6 $mg.L^{-1}$ (Table 19). Chloride concentrations showed some relationship to flow in both streams. High concentrations were more prevalent at low ranges of flow, in spite of a tenfold greater

range in flows at Bewdley South (Figure 4.1, 4.2). At Bewdley South, all concentrations of <5 $mg.L^{-1}$, with one exception, were found in the lower 5% of flows. Chloride concentrations were highest during the November to March winter period, reflecting road salt applications on major roads 20 m upstream of the sampling sites in each stream. Chloride concentrations at Bewdley South responded to the spring freshet with major increases in each year (Fig 5.8) but no such response was seen at Bewdley North (Figure 5.7). The higher proportion of cleared agricultural land in the Bewdley South watershed (Table 6) may have contributed to this pattern.

Table 20: Increases in mean annual concentrations of sodium and chloride in Rice Lake tributary streams, 1986-1988

		Sodium		Chloride		Annual Change (ueq/L)	
		Mean	SD	Mean	SD	Sodium	Chloride
Ouse River	1986	5.0^{A}	1.01	10.1^{A}	2.21		
	1987	7.5^{B}	3.27	15.1^{B}	5.66	112	140
	1988	8.7^{C}	3.28	19.2^{C}	6.19	54	115
Indian River	1986	4.3^{A}	0.88	8.4^{A}	2.06		
	1987	4.6^{AB}	1.15	8.9^{A}	2.32	13.0	14.0
	1988	4.8^{B}	2.1	10.2^{B}	3.82	9.0	8.0
Otonabee R.	1986	4.7^{A}	0.91	8.2^{A}	1.88		
	1987	5.6^{B}	1.31	9.6^{B}	2.18	41.0	39.0
	1988	5.6^{B}	0.89	10.5^{C}	2.06	0	25.0
Trent River	1986	4.68^{A}	0.40	8.3^{A}	0.96		
	1987	5.23^{B}	0.59	9.1^{B}	0.97	23.0	22.0
	1988	5.37^{B}	0.68	9.8^{C}	1.07	9.0	20.0

Concentrations are given in $mg{\cdot}L^{-1}$ and identical superscripts denote mean values which were not significantly different ($p < 0.05$) for between-year comparisons.

The Ouse River site had a higher proportion of high (>12 $mg.L^{-1}$) chloride values than any other Rice Lake site (Figure 2.2A). Nearly 45% of all measurements were >12 $mg.L^{-1}$ and nearly 20% exceeded 20 $mg.L^{-1}$. The median concentration was 11.2. Chloride concentration was very much flow dependent. All values greater than 12 $mg.L^{-1}$ were recorded in the lower 10 % of the range of flow (0-2.5 $m^3.s^{-1}$, Figure 4.4). As a result, the annual patterns (Figure 5.10) showed high values during the winter months and no increase accompanying the spring freshet. Instead, peak concentrations were recorded in August to September of each year, during the period of lowest flow. This pattern suggests a constant load of chloride to the Ouse River which is concentrated during low flow periods. Mean annual chloride concentrations increased from 10.1 to 15.1 to 19.2 during the three years of the study (Table 20) and all increases were significant ($p<0.05$). Chloride concentrations in the Indian River were intermediate to those in the Bewdley streams and the Ouse River. About 75% of all measurements were between 6 and 10 $mg.L^{-1}$ and less than 6% were above 16 $mg.L^{-1}$ (Figure 2.2A). The median concentration was 8.3 $mg.L^{-1}$ (Table 19). High concentrations of chloride were mostly confined to the lower 20% of measured flows. Only 2 of nearly 50 values greater than 12 mg.L-1 were measured at flows above 3500 $L.sec^{-1}$ (Figure 4.3). Chloride concentrations were lowest in the May to September low flow period, then increased gradually to maximum concentrations in February and March (Figure 5.9). The spring freshet appeared to dilute chloride concentrations, which is also suggested by the concentration/flow relationship discussed above. Chloride concentrations were significantly ($p<0.05$) higher in the third year of the study than in the first two years (Table 20).

The regulated flows of the Otonabee River and the lakes upstream controlled chloride concentrations to a narrower range than in the other inflows to Rice Lake. As a result, 55% of all concentrations were between 8 and 10 $mg.L^{-1}$ and <10% were above 14 $mg.L^{-1}$ (Figure 2.2A). The median chloride concentration was 9.1 $mg.L^{-1}$. No clear relationship between concentration and flow was apparent other than a tendency for higher concentrations to be found at the lower half of the measured flow values (Figure 4.5). Chloride concentrations increased from minima between June and November to high values between December and March, followed by dilution during the spring freshet (Figure 5.11). Significant increases in concentration occurred between each year of the study (from 8.2 to 9.6 to 10.5 $mg.L^{-1}$ in 1986, 1987 and 1988, respectively (Table 20)).

The buffering effect of Rice Lake on variable chloride inputs produced the narrowest range of concentrations at the Trent River outflow. No measurements exceeded 14 $mg.L^{-1}$, 64% were between 8 and 10 $mg.L^{-1}$ and the median value was 9.0 $mg.L^{-1}$ (Figure 2.2A, Tab.19). Although high concentrations were found less often at high flows the relationship between concentration and flow was very weak (Figure 4.6). Minimum concentrations were measured in the April-June period and maximum values between December and March. Chloride showed significant increases in each year of the study just as it did at the stations on Rice Lake (Table 10). Concentrations were 8.3, 9.1 and 9.8 $mg.L^{-1}$ in 1986, 1987 and 1988 (Table 20).

Increased chloride concentrations at the Ouse, Indian, Otonabee and Trent Rivers between 1986 and 1989 were likely a function of hydrologic changes. Chloride concentrations at these sites showed a tendency to increase as flow decreased (Figures 4.3 to 4.6). This was most pronounced in the Ouse River (Figure 4.4) where chloride concentrations nearly doubled from year 1 to year 3 (Table 20). Figure 38 in Hutchinson et al. (1993 a) showed that discharge of all streams decreased over the course of the study. The decrease was most pronounced for the Ouse River. Total discharge in year 3 was only 45.63×10^6 m^3 compared to 83.12×10^6 m^3 in year 1. High chloride concentrations were thus a function of reduced runoff and discharge.

Chloride concentrations increased more than Na concentrations in the Ouse River when expressed on a molar basis. This suggests that road salt and hydrology were not the only influences since these would have increased both ions equally. The use of $CaCl_2$ as a dust suppressant on roads was common and may have contributed to the patterns observed in the Ouse River. Sodium and chloride concentrations inceased equally or variably in the other streams (Table 20).

Potassium

Bewdley North had the lowest potassium concentrations of any of the Rice Lake tributaries (Median = 0.88 $mg.L^{-1}$, Table 19). Seventy percent of all measurements were between 0.6 and 1.2 $mg.L^{-1}$ and only 8% were >1.4 $mg.L^{-1}$ (Figure 2.3A). There was no relation between potassium and discharge (Figure 4.1) other than a tendency for very low concentrations in the lower 20% of flows. Little seasonal effect on concentration was observed aside from an increase in autumn and during the February-March freshet (Figure 5.19).

Potassium distributions at the Bewdley South site were opposite of those at Bewdley North and concentrations were higher than at any of the Rice Lake tributaries. Over 40% of the values measured were over 2.0 $mg.L^{-1}$ and <10% were <1.2 $mg.L^{-1}$ (Figure 2.3A). The median concentration was twice that of Bewdley North (1.7 $mg.L^{-1}$,Table 19). Increased concentrations during the spring freshet were pronounced and minimum values were recorded in the June to September growing period (Figure 5.20). There was no relationship between concentration and discharge but minimum values were often recorded in the lower 15% of flow (Figure 4.2).

The Indian and Ouse Rivers had similar distributions of potassium concentrations. Median concentrations were 1.18 and 1.21 $mg.L^{-1}$ respectively (Table 19). In both streams 60-70% of all measurements were between 0.8 and 1.4 $mg.L^{-1}$ and 12% were >2.0 $mg.L^{-1}$ (Figure 2.3A). Both streams showed maximum concentrations associated with the March-April freshet and sharp increases during mid-winter thaws (Figures 5.21, 5.22). Concentrations in the Ouse River also showed a sharp increase between July and October. This was most pronounced during the 1987 and 1988 droughts (Figure 5.22). This pattern suggests a constant supply of potassium which was diluted as flow increased. Figure 4.4 shows that high concentrations were confined to the lower 20% of flows. High potassium concentrations were found across the entire range of flow in the Indian River but the baseline of minimum concentration increased with discharge. Minimum concentrations of 0.75 $mg.L^{-1}$ were recorded at the lower 20% of discharges and 1.4 $mg.L^{-1}$ in the upper 60% of discharges (Figure 4.3).

The Otonabee River had the same median potassium concentration as the Indian and Ouse rivers (1.18 $mg.L^{-1}$–, Table 19) but the distribution of concentrations was narrower. Nearly 80% of all values were between 1.0 and 1.4 $mg.L^{-1}$ and <2% were below 0.8 or above 2.0 $mg.L^{-1}$ (Figure 2.3A). There was a tendency towards higher concentrations during the spring freshet and concentrations declined over the summer to minima in September and October (Figure 5.23). All concentrations >1.2 $mg.L^{-1}$, with one exception, were recorded at flows of < 150 $m^3.s^{-1}$ during winter thaws and the spring freshet (Figure 4.5).

The distribution of potassium concentrations at the Trent River site reflected buffering of extreme concentrations by Rice Lake and uptake and release of potassium by

Potamogeton crispus. The median concentration (1.17 $mg.L^{-1}$) was the same as for the major inflows to Rice Lake (Table 19) and 75% of the measured values fell between 0.8 and 1.4 $mg.L^{-1}$. This is shown clearly in Figure 4.6 as a tight distribution of concentrations at all flows . Only 1 value between June 1986 and June 1989 exceeded 2.0 $mg.L^{-1}$. The seasonal pattern showed two distinct maxima. The first reflected the March-April spring freshet. A steep drop in concentration between April and late May reflects uptake of potassium by growth of P. crispus and the increase over the summer reflects decomposition of P. crispus and release of potassium back to the water column (Figure 5.24). The autumn decrease may be a function of increased flow and resultant dilution of potassium concentration.

Nitrogen

The distribution of ammonia measurements was similar in the four smaller Rice Lake tributaries. Median concentrations of 22, 28, 30, and 42 $\mu g.L^{-1}$ were measured at Bewdley South, Bewdley North, the Indian and Ouse Rivers respectively (Table 19). All had 70-85% of measurements < 60 $\mu g.L^{-1}$ (Figure 2.5A). Bewdley South had nearly 20% of its measurements >200 $\mu g.L^{-1}$. The Otonabee River showed the influence of discharge from the Peterborough STP. Median ammonia concentration was 86 $\mu g.L^{-1}$ and 65% of all measurements were between 40 and 140 $\mu g.L^{-1}$ (Figure 2.5A). This enrichment was still apparent at the Trent River (median = 62 $\mu g.L^{-1}$, Table 19) and at all Rice Lake stations (median = 60 $\mu g.L^{-1}$, Tables 8,11).

The Bewdley streams were enriched in nitrates and reduced in Kjeldahl nitrogen compared to the other streams. The nitrate/Kjeldahl ratios were 3.2:1 and 7.3:1 in the two Bewdley streams, and 0.16:1 to 0.89:1 in the other streams. These two watersheds contained only agricultural and dry woodland land use compared to other catchments which contained some wetland areas (Table 6). At Bewdley South, 94% of all nitrate measurements exceeded 1000 $\mu g.L^{-1}$ and 70% were between 1600 and 2000 $\mu g.L^{-1}$. Nitrate concentrations were similar in the Indian, Otonabee and Trent Rivers with 65% of all values <200 $\mu g.L^{-1}$ (Figure 2.7A). Median concentrations of Kjeldahl nitrogen were 250 and 270 $\mu g.L^{-1}$ in Bewdley North and Bewdley South respectively compared to 460 to 520 $\mu g.L^{-1}$ in the remaining streams (Table 19).

Ammonia concentrations showed large and irregular increases at Bewdley South during the winter months and the spring freshet compared to Bewdley North where they were more stable (Figures 5.13, 5.14). During winter and spring freshets, the ratio of nitrate to ammonia declined to near 1:1, suggesting contamination from agricultural runoff (Wetzel 1975). Ammonia concentrations were equal to or exceeded nitrate concentrations between April and October in the Indian River (Figure 5.15). This was largely a result of uptake of nitrate by vegetation since ammonia concentrations peaked during the winter. The ammonia:nitrate ratio showed the same seasonal pattern in the Otonabee River. This could not be attributed to nitrate uptake since 1986

was the only year in which nitrate was obviously lower in the summer months (Figure 5.17). Increased ammonia concentrations as a result of less dilution of STP effluent at low discharge may explain this pattern in the Otonabee River. Dilution may also explain the patterns of ammonia and nitrate in the Ouse River. Nitrate showed little response to the cycle of terrestrial vegetation growth (Figure 5.16)but did drop during the spring freshet. Ammonia concentrations dropped during the October-December wet period and again during the freshet. Nitrate concentrations exceeded ammonia concentrations at all times except during the drought period in July 1988.

Table 21: Monthly mean and standard deviation of N:P ratio in Rice Lake, measured at the outflow at Hastings, N:P ratio = nitrate + Kjeldahl nitrogen/total phosphorus, calculated on a molar basis.

Year	Month	x̄	SD	Year	x̄	SD	Year	x̄	SD	Year	x̄	SD
1986	Jan	-	-	1987	351	108	1988	403	95	1989	409	82
	Feb	651	23		594	131		575	43		490	44
	Mar	950	83		701	107		641	72		501	50
	Apr	550	113		397	152		463	130		597	141
	May	92	44		114	40		164	81		166	85
	Jun	87	26		90	16		95	23		-	-
	Jul	97	40		95	19		98	7		-	-
	Aug	89	23		147	55		108	4		-	-
	Sept	101	19		97	18		90	22		-	-
	Oct	118	47		174	24		223	77		-	-
	Nov	105	26		255	39		334	0		-	-
	Dec	268	77		405	83		344	51		-	-

Nitrogen measurements at the Trent River reflected sewage treatment plant inputs to the Otonabee River in Peterborough and biological cycling within Rice Lake. Ammonia concentrations were enriched and showed a strong peak in September-October and a smaller peak in February and March (Figure 5.18). Nitrate concentrations peaked during the late winter and early spring, dropped during the onset of macrophyte and terrestrial plant growth in April and remained generally low until October when plant growth ceased (Figure 16). As a result, ammonia concentrations exceeded nitrate concentrations during the summer period of all years. Kjeldahl nitrogen concentrations followed the growth of phytoplankton, showing maximum values in August and September. Monthly values of the N:P ratio in the Trent River outlet ranged from 87:1 to 950:1 when expressed on a molar basis, indicating that nitrogen limitation did not occur in Rice Lake (Table 21). The minimum value of 47:1 was recorded in June 1986.

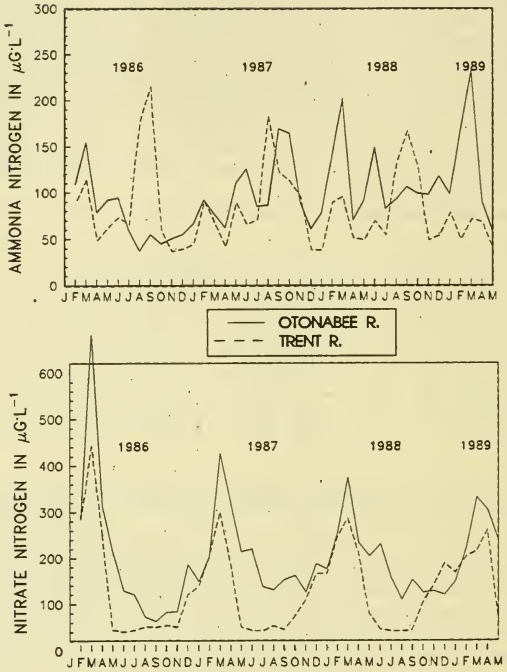
AMMONIA NITROGEN IN µG·L⁻¹
300
250
200
150
100
50
0
1986
1987
1988
1989
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M
OTONABEE R.
TRENT R.
NITRATE NITROGEN IN µG·L⁻¹
600
500
400
300
200
100
0
1986
1987
1988
1989
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M

Figure 16: Nitrogen cycling in Rice Lake

Ephemeral Stream

Agricultural runoff was the apparent reason for severely degraded water quality in a small ephemeral stream which discharged into the Otonabee River near Campbelltown during periods of high runoff. Although not a regular water quality site, this stream and a small tributary upstream were sampled whenever they were flowing by a local observer, who also provided the map of local land use (Figure 4). Mean values of conductivity, sodium, chloride and potassium were elevated by factors of 1.8, 1.6, 2.3 and 8.8 respectively in this stream, compared to the Otonabee River (Tables 19 and 22). Of more importance were nutrient levels in the stream. The mean value of total phosphorus (613 $\mu g.L^{-1}$) was 2.1 times higher than the maximum value recorded in the Otonabee River in three years and four measurements >1.0 $mg.L^{-1}$ were measured. Available orthophosphate levels were also extremely high. Although ammonium levels were also high, the low pH and temperature conditions prevailing during runoff events likely prevented the formation of significant amounts of toxic un-ionized ammonia (MOE.1984). Ammonia levels exceeded nitrate levels on many occasions, suggesting that agricultural runoff was a likely source of contamination (Wetzel 1975). Observations of yellow-brown effluent in the stream draining a chicken broiler operation and several cattle lots upstream are confirmation of the source of this highly degraded water.

Water Chemistry In Rice Lake During Senescence of P. crispus, 1987

In addition to nutrient inputs from the watershed, the trophic status of a lake can be affected by processes which occur within the lake. The decay of macrophytes can have a significant impact on nutrient cycling in some lakes. Rooted plants link the sediment with overlying water, and root uptake of phosphorus is usually the most important source of phosphorus nutrition to these plants (Bristow and Whitcombe, 1971; Gentner, 1977; Best and Mantai, 1978). Nutrients and organic matter can be translocated to the water by macrophyte shoots (Twilley et al., 1977), and can be released to the water column during decomposition (Otsuki and Wetzel, 1974; Godshalk and Wetzel 1978). In some lakes, this process can be a significant nutrient load (Carpenter, 1980).

An intensive survey of Rice Lake water chemistry was conducted from June 8 to June 18, 1987. The dates for the survey were selected to coincide with the annual die-off of the dominant macrophyte in the lake, Potamogeton crispus. The purpose of the survey was to determine if there were measurable changes in selected water chemistry parameters during the die-off, and to provide estimates of chemical heterogeneity in the lake water.

Table 22: Summary of water quality in an ephemeral stream draining farmland adjacent to the Otonabee River at Cambellitown. Locations of sampling points are shown in Fig 4.

Site 1 : Mouth of creek 200m upstream of Campbelltown dock.

Date	Na ($mg.L^{-1}$)	K ($mg.L^{-1}$)	Cl ($mg.L^{-1}$)	TP ($\mu g.L^{-1}$)	PO_4 ($\mu g.L^{-1}$)	TKN ($\mu g.L^{-1}$)	NH_4 ($\mu g.L^{-1}$)	NO_3 ($\mu g.L^{-1}$)
870323	6.4	5.1	16.7	64	42	930	202	5000
870402	12.4	7.7	32.7	126	91	1450	474	6520
870405	7.6	6.2	20.1	171	–	1050	130	5670
880201	8.5	13.0	20.3	715	435	5300	2860	1480
880310	4.8	6.9	11.2	63	–	3500	1340	1210
880314	11.2	8.3	27.7	189	56	1600	340	2020
880324	8.4	5.9	21.9	235	–	1600	654	1030
880328	9.9	20.1	22.5	163	65	1780	596	985
	10.7	8.0	27.5	126	72	1950	820	3160
880404	11.5	8.1	30.5	127	73	1590	336	3120
890130	8.4	16.4	21.0	1550	1430	7100	4240	1110
	7.8	15.7	20.5	1550	1330	6500	3640	1410
890201	7.5	13.1	19.2	1250	905	5100	2370	1360
890316	6.3	12.0	16.7	2250	900	8750	2700	1340
Mean	**8.7**	**10.5**	**22.0**	**613**	**491**	**3443**	**1479**	**2530**
S.D.	**2.2**	**4.6**	**5.8**	**728**	**549**	**2606**	**1400**	**1890**

Site 2 : Culvert draining field 1500 m upstream of creek mouth.

880310	3.5	7.8	9.6	600	328	4850	1440	1840
	4.6	7.8	10.1	815	555	3450	668	795
880328	9.1	8.6	24.2	137	76	1870	636	3250
Mean	**5.7**	**8.1**	**14.6**	**517**	**320**	**3390**	**915**	**1962**
S.D.	**3.0**	**0.5**	**8.3**	**346**	**240**	**1491**	**455**	**1232**

The Macrophyte Community of Rice Lake : 1986-1987

In 1987, a survey of the macrophytes in Rice Lake showed that the P. crispus beds covered 5558 ha, or about 60% of the lake bottom at peak growth in early June (Limnos 1988). The second most common macrophyte was Myriophyllum spicatum (Eurasian watermilfoil) which covered an estimated area of 1350 ha or 15% of the lake bottom. The P. crispus beds senesced in June and were virtually absent from the lake by the fall. The milfoil beds were declining in vigour by early September and some of the more exposed beds had disappeared.

Biomass and Elemental Storage in Macrophytes

Two estimates of aquatic macrophyte biomass and elemental storage were made as part of the Limnos surveys. In June 1987, there were an estimated 91150 tonnes (wet weight) of P. crispus in the lake. This amounted to 8204 tonnes dry weight, and contained an estimated 11.9 tonnes of phosphorus, 122.9 tonnes of nitrogen, and 150 tonnes of potassium (Table 23). The estimates of total macrophyte biomass in the lake were 102350 tonnes wet weight or 9540 tonnes dry weight. This biomass contained an estimated 16.2 tonnes of phosphorus, 148.3 tonnes of nitrogen, and 153.8 tonnes of potassium.

Figure 17: Location of 43 sites in Rice Lake sampled during the period of maximum biomass and senesence of Potamogeton crispus, 1987.

In September 1986, the total wet weight of macrophytes (mostly milfoil) was estimated to be 12650 tonnes wet weight, or 1472 tonnes dry (Table 23). The elemental storage was 5.1 tonnes of phosphorus, 33.7 tonnes of nitrogen, and 6.5 tonnes of potassium.

The differences in elemental storage in the macrophytes between June and September mean that a large reservoir of nutrients was relocated as a result of the senescence of the P. crispus beds in early summer. The estimated 11.1 tonnes of translocated phosphorus is very close to the estimate of total phosphorus stored in the P. crispus community at peak growth in June. The fate of those nutrients has potentially large ramifications to the overall nutrient budget of Rice Lake.

Sampling Methods

A total of 43 sampling sites were selected on Rice Lake, based on the maps of macrophyte distribution prepared in 1986 (Limnos, 1988). These locations are shown in Figure 17. Each day between June 8 and 18, 1987, samples of water were taken at each site at 1m below the surface (referred to as surface samples), and 1m from the bottom (referred to as bottom samples). The water temperature and Secchi depth

were also recorded at each site (although the Secchi disc was frequently obscured by macrophytes).

Table 23: Total wet mass, dry mass and contained nutrients (tonnes) for major macrophyte species and communities in Rice Lake, 1986 and 1987. (Limnos 1988)

Species or Community	Wet Mass	Dry Mass	Total P	Total K
Spring-Early Summer				
Potamogeton crispus	91150	8200	11.9	150
Myriophyllum spicatum	11200	1340	4.3	3.8
Total	**102350**	**9540**	**16.2**	**153.8**
Early Autumn				
Myriophyllum spicatum	8100	972	3.2	2.8
Mixed Community	4550	500	1.9	3.7
Total	**12650**	**1472**	**5.1**	**6.5**

Analyses

Each sample was analyzed for soluble reactive phosphorus (SRP), total phosphorus, and potassium. The two phosphorus analyses were done in the mobile laboratory operated by the Water Quality Section of the MOE Laboratory Services Branch. While none of the samples were filtered, the particulate matter in the sampling containers was permitted to settle and an aliquot of the supernatant liquid was taken for the phosphorus analyses. Typical intervals between sample collection and analysis for soluble reactive phosphorus were on the order of three or four hours. Total phosphorus analyses were done in the mobile laboratory with the exception of the samples for June 8 and 9. These samples were analyzed at the MOE Laboratory in Rexdale. The potassium analyses were also performed in the Rexdale Lab with a delay of about two weeks. All analyses were done according to standard methods outlined in MOE (1981).

RESULTS

Temperature

The mean water temperature of the lake can change significantly within 24 hours as shown in Figure 18. During the course of the survey the mean water temperature ranged from 17.1 to 22.0 °C. There was no significant difference between water temperature in the surface sample and the bottom sample, reflecting the complete mixing of the water column.

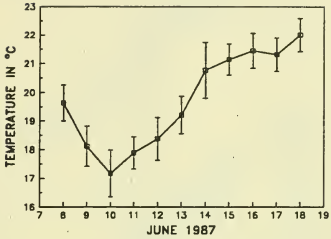

Figure 18: Water temperatures (mean ± 1 s.d.) in Rice Lake, June 8-18, 1987.

Secchi Depth

The mean Secchi depth varied from 2.6 to 3.1 m and showed no consistent relationship to either time or location on the lake. In the first few days of the survey the Secchi disc was frequently obscured by macrophytes. The number of stations where Secchi depth could be measured increased as the P. crispus beds collapsed.

Soluble Reactive Phosphorus

Most samples had no detectable SRP (detection limit 0.5 $\mu g.L^{-1}$, Table 24). There were no significant trends in either surface or bottom concentrations of SRP during the course of the intensive survey. The overall mean (all stations, all days) of the surface SRP was 0.20 $\mu g.L^{-1}$, significantly lower than the SRP measured at the bottom of the lake (0.32 $\mu g.L^{-1}$, Table 24). The spatial distribution of SRP was quite heterogeneous on a daily basis. Over the course of the survey only the southwest end of the lake near Bewdley had surface SRP concentrations consistently above the detection limit. In addition to the Bewdley area, samples taken near the mouth of the Otonabee and the Indian Rivers had bottom water concentrations consistently above the detection limit.

Table 24: Concentrations of soluble reactive phosphorus, total phosphorus and potassium measured at 43 locations in Rice Lake between June 8 and June 16, 1987.

SURFACE WATER SAMPLES

Date	Soluble Reactive Phosphorus	Total Phosphorus	Potassium
870608	0.274(0.496)	12.87(5.97)	912(176)
870609	0.198(0.396)	14.07(5.86)	955(179)
870610	0.270(0.388)	13.16(5.61)	972(177)
870611	0.214(1.164)	-	978(174)
870612	0.274(0.431)	12.57(6.25)	1020(161)
870613	0.048(0.149)	11.06(3.80)	1023(179)
870614	0.119(0.453)	13.38(7.58)	1051(192)
870615	0.274(0.416)	13.48(6.52)	1063(182)
870616	0.333(0.477)	12.75(4.38)	1129(180)
870617	0.131(0.383)	11.05(4.52)	1137(180)
870618	0.122(0.311)	13.44(4.40)	1138(180)
Mean	**0.210(0.530)**	**13.20(9.92)**	**1026(187)**

BOTTOM WATER SAMPLES

Date	Soluble Reactive Phosphorus	Total Phosphorus	Potassium
870608	0.512(1.045)	15.13(9.67)	937(221)
870609	0.547(0.793)	29.15(25.4)	981(190)
870610	67(0.816)	25.27(23.1)	1010(181)
870611	0.298(0.988)	-	966(163)
870612	0.274(0.416)	11.93(4.47)	1036(161)
870613	0.143(0.354)	13.57(6.51)	1040(190)
870614	0.159(0.720)	13.43(6.05)	1074(202)
870615	0.250(0.317)	13.32(5.28)	1064(183)
870616	0.381(0.492)	13.33(5.61)	1081(177)
870617	0.155(0.420)	13.02(5.79)	1133(179)
870618	0.179(0.395)	14.45(5.10)	1151(184)
MEAN	**0.320(0.68)**	**18.1 (22.4)**	**1041(192)**

Values given are mean and (standard deviation) for surface and bottom samples in $\mu g.L^{-1}$. Concentrations of SRP below the detection limit of $0.5 \mu g.L^{-1}$ were entered as 0 for all calculations. Samples from June 11 were not analyzed for total phosphorus.

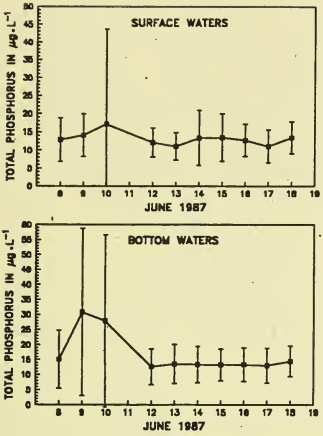

Figure 19: Total phosphorus concentrations ($\mu g.L^{-1}$) in Rice Lake, June 8-18, 1987.

Figure 20: Spatial distribution of total phosphorus in Rice Lake, June 8-18, 1987.

Total Phosphorus

There was no significant change in the total phosphorus concentration of Rice Lake during the intensive sampling period (Table 24). There was a pulse of total phosphorus observed on June 9 and 10 in both surface and bottom samples (Figure 19). As with SRP the overall mean of the samples taken near the bottom was higher (18.1 $\mu g.L^{-1}$) than the mean of surface water samples (13.2 $\mu g.L^{-1}$, Table 24). For the first five or six days there were small areas of increased TP concentration at several locations in the lake but differences were minimal by the end of the study. Overall, surface and bottom samples taken near the Bewdley area had phosphorus concentrations which were consistently higher than those from the rest of the lake (Figure 20). This is consistent with data from three summer surveys (Table 13) which showed that the west end of Rice Lake had higher TP concentrations than the rest of the lake. The Serpent Mounds area was also higher in bottom water phosphorus concentration.

Potassium

The potassium concentration of the lake rose steadily during the course of the survey (Figure 21, Table 24). Potassium concentrations in the Trent River at Hastings increased over the same time period but took 10 days to reach the average lake concentration measured during the survey (Figure 22). There was a strong correlation between the potassium concentration measured in surface samples and the concentrations measured in bottom samples from the same station in the lake (r^2 = 0.83). Potassium was consistently highest in the middle of the lake and lowest near the outlet and in a band between the Otonabee inflow and Bewdley.

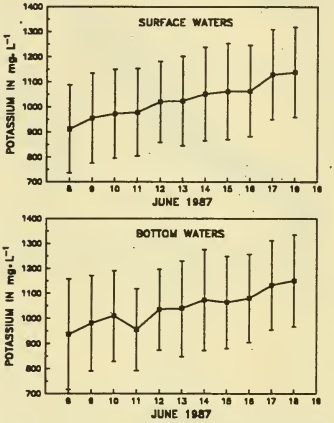

Figure 21: Potassium concentrations ($\mu g.L^{-1}$) in Rice Lake, June 8-18, 1987

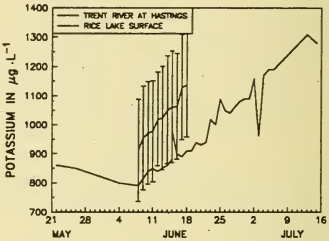

Figure 22: Potassium concentrations ($\mu g.L^{-1}$) in Rice Lake, June 8-18, 1987, (upper line, mean+/- 1SD) compared to those measured in the Trent River outflow.

Water Chemistry and Macrophyte Beds

The sampling crew noted which macrophyte species were present and which dominated at each station on each day of the survey. Total phosphorus, SRP and potassium concentrations in both surface and bottom waters were usually higher in macrophyte beds than in open water (Figure 23, 24). Concentrations of TP were higher in beds dominated by P. crispus than in those dominated by M. spicatum. This was most apparent on the first four days of the survey (Figure 23). Potassium concentrations were higher within M. spicatum beds. Some of these results may reflect higher concentrations of particulates inside the macrophyte beds than outside. The

macrophytes invariably obscured the Secchi disc when they were present and no other measure of water clarity was taken.

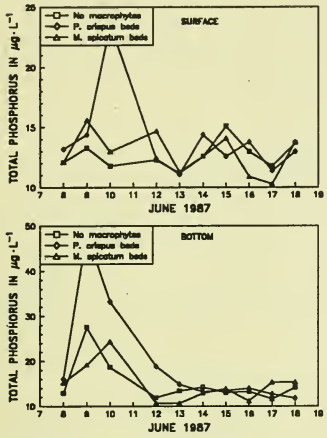

Figure 23: Effects of aquatic macrophyte presence on total phosphorus in Rice Lake, June 8-18, 1987.

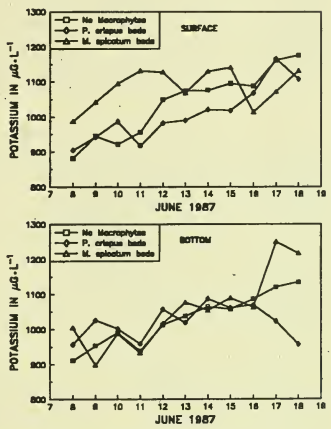

Figure 24: Effects of aquatic macrophyte presence on potassium in Rice Lake, June 8-18, 1987.

Estimates of the Elemental Pool In the Water Column

The mean concentration of total phosphorus (15.6 $\mu g.L^{-1}$) and the volume of Rice Lake (2.04×10^8 m^3) produced an estimated total of 3752 kg of phosphorus in the lake during the course of the survey. The potassium concentration varied significantly during the course of the survey. On June 8 the estimate of the pool of potassium in the water column was 188.6 tonnes while on June 18, the estimate was 233.5 tonnes. During the eleven days of the survey the water column pool of potassium increased by 44.9 tonnes. This was 30% of the estimated total mass of 150 tonnes of potassium which was contained in the P. crispus community in June 1987 (Table 23). More detailed discussions of nutrient/macrophyte interactions will be presented in the summary report of Rice & Sturgeon Lake Study (Hutchinson et al. 1993d)

Discussion

Total phosphorus concentrations did not change appreciably during the course of the intensive survey. The potassium concentration of the lake rose significantly and was relatively uniform throughout the water column. Potassium concentration at the Trent River outflow from Rice Lake decreased during the period of P. crispus growth beginning in March and increased following the senescence period (Figures 22,4.24). The source of increased potassium concentrations during the June survey was release of this element during the senescence of the P. crispus beds.

The fate of the phosphorus contained in the P. crispus community is uncertain. If all 11.9 tonnes of the phosphorus stored in the P. crispus community (1988 estimate, Table 23) were to dissolve in the water column upon senescence an increase in concentration of approximately 48 $\mu g.L^{-1}$ would have been seen. Even prorating this estimate to the actual increase observed for the potassium (30%) an increase of close to 14.4 $\mu g.L^{-1}$ would be expected. Figures 13 and 4.6 show that TP concentration in the Trent River outflow at Hastings rose by approximately 20 $\mu g.L^{-1}$ during June of each year of the study. Some of this increase may represent phosphorus loss from the P. crispus community but if this export is occurring, it is too far removed from the actual period of senescence to represent an immediate response or phosphorus loss.

The majority of the phosphorus in the P. crispus evidently translocates to the sediment. Other sinks for this phosphorus include increases in M. spicatum biomass and storage in turions. The increase of phosphorus measured in the Trent River in autumn may represent a loss of some of this translocated phosphorus (see Figure 5.6). This issue will be discussed further in the summary report (Hutchinson et al. 1993d)

RESULTS AND DISCUSSION - STURGEON LAKE

Lake Chemistry

A statistical summary of water quality measurements made at all Sturgeon Lake sites is given in Table 25. Tables 1.17 to 1.22 (App. 1) present detailed summaries for each of the six individual lake stations. Histograms of the distribution frequency of water quality measurements are presented in Figures 3.1C to 3.8C and 3.9A (App. 3).

Analysis of variance revealed distinct between-station differences in water chemistry of Sturgeon Lake. Station 6 at the north end of the lake was the station closest to the major inflow to Sturgeon Lake at Fenelon Falls. Concentrations of chloride and potassium, and conductivity measurements were significantly lower at Station 6 than at all other stations (Tables 25, 26).

Sodium concentrations were lower at Station 6 than at Stations 7 and 8, but were not significantly different from other stations.

Major ion concentrations at Station 6 reflected the inflow of dilute Precambrian shield drainage to Sturgeon Lake from Fenelon Falls. Figure 25 shows that chloride concentrations at Station 6 were midway between those at Fenelon Falls and those for the rest of lake throughout the ice-free period of all three years. The average chloride concentrations measured over the study were 4.2±0.5, 5.1±0.7 and 6.9±1.6 $mg \cdot L^{-1}$ for the Fenelon Falls inflow, Station 6 and the rest of Sturgeon Lake respectively.

Table 25: Water quality statistics for all stations in Sturgeon Lake: 1986-1988.

	Total Phosphorus ($\mu g.L^{-1}$)	Chlorophyll a ($\mu g.L^{-1}$)	Kjeldahl Nitrogen ($\mu g.L^{-1}$)	Conductivity ($\mu S/cm$)
Mean	27	11.2	568	218
Std. Deviation	23	19.6	283	81
Minimum	5	0.3	260	125
Maximum	139	240.0	1880	485
Median	19	6.8	460	192
First/Third Quartiles	14/30	4.1/13.2	400/620	173/213
Number of Samples	200	170	200	202

	Ammonium ($\mu g.L^{-1}$)	Nitrite ($\mu g.L^{-1}$)	Nitrate ($\mu g.L^{-1}$)
Mean	58	7.0	72
Std. Deviation	56	9.0	104
Minimum	2	1.0	5
Maximum	398	88.0	925
Median	44	4.0	35
First/Third Quartiles	26/66	3.0/7.0	20/75
Number of Samples	201	201	201

	Sodium ($mg.L^{-1}$)	Chloride ($mg.L^{-1}$)	Potassium ($mg.L^{-1}$)
Mean	5.25	9.03	1.19
Std. Deviation	3.93	6.39	0.48
Minimum	2.31	3.75	0.74
Maximum	24.20	35.00	3.11
Median	3.83	6.70	1.01
First/Third Quartiles	3.57/4.19	6.00/7.50	0.93/1.14
Number of Samples	202	200	202

Table 26: Comparison of water quality at six sites in Sturgeon Lake for May-October of 1986-88. Between station differences were significant ($p<0.05$) where individual station means are presented.

	Station 6			Station 8			Remaining Stations		
Parameter	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**
Chloride	5.13	0.72	26	23.3	5.45	29	6.9	1.55	121
Conductivity	157	18	27	395	41	29	193	27	121
Potassium	0.88	0.07	27	2.3	0.34	29	1.03	0.16	121
Sodium				13.7	4.42	29	3.8	0.68	148
Ammonia - N				124	111	29	44.4	25.4	147
Nitrite - N				15.9	17.1	29	5.0	4.56	147
Nitrate - N				139	145	29	55.6	58.8	147
Kjeldahl - N				1083	259	29	471	170	146
Total Phosphorus				65.7	29.3	29	19.2	12.67	146
Chl *a* - total				22.6	35.1	29	5.7	4.17	139
Chl *a* - corrected				29.9	41.7	29	7.4	5.17	140
Secchi depth				0.7	0.4	27	2.7	0.9	136

Station 8 was located at the south end of Sturgeon Lake, near the town of Lindsay. Concentrations of all measured parameters were significantly higher at Station 8 than at the rest of the Sturgeon Lake stations (Table 26). Nutrient enrichment was apparent for all nitrogen, phosphorus and chlorophyll *a* measurements; and the influence of higher conductivity water apparent from concentrations of sodium, chloride and potassium (Table 26). Figures 26 to 29 show that measurements of chloride, total phosphorus, potassium and ammonia from Station 8 closely matched the concentration and seasonal patterns of the same parameters measured in the Scugog River at Lindsay. The same patterns were observed for nitrate and Kjeldahl nitrogen.

Monthly discharges of effluent from the Lindsay sewage lagoons near Station 8 also contributed to the observed nutrient enrichment. Monthly loads from the lagoons ranged from 35 to 642 kg TP over the course of the study, compared to loadings of 73 to 1924 kg from the Scugog River (Hutchinson et al 1993c). Phosphorus loadings from the lagoons exceeded those from the Scugog River in 14 of the 36 months of monitoring and were 31 to 71% of river loadings on an annual basis. In 15 of 18 summer months for which data existed, mean TP concentrations at Stn. 8 exceeded those measured in the Scugog River. In 7 of the 15 months, loadings from the STP exceeded those from the river. The Lindsay sewage lagoons certainly contribute to the eutrophication but the patterns discussed above suggest that the Scugog River influence dominates water quality at Station 8. The water chemistry at Stations 7, 9, 10 and 11 represents mixing of a small volume of high conductivity Scugog River water with a large volume of low conductivity water from the inflow at Fenelon Falls.

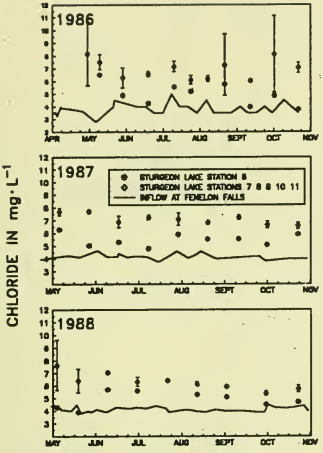

Figure 25: Influence of Fenelon Falls inflow on chloride concentrations at Sturgeon Lake Station 6.

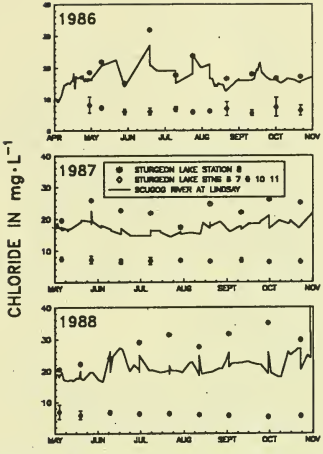

Figure 26: Influence of Scugog River on chloride concentrations at Sturgeon Lake Station 8.

No monthly or annual patterns in water chemistry of Sturgeon Lake were apparent with two exceptions. Chloride concentrations at Station 8 rose significantly in each year of the study; from 19.8 ± 5.3 $mg{\cdot}L^{-1}$ in 1986, to 22.7 ± 3.0 $mg{\cdot}L^{-1}$ in 1987, to 27.91 ± 4.8$mg{\cdot}L^{-1}$ in 1988. Sodium concentrations at Station 8 were 12.7 ± 6.0 in 1986, and 13.0 ± 2.3 $mg{\cdot}L^{-1}$ in 1987 compared to 15.9 ± 3.6 $mg{\cdot}L^{-1}$ in 1988.

Stations 7, 9, 10 and 11 were chosen to represent whole-lake mean chloride concentrations and to exclude the effects of the Fenelon Falls and Scugog River inflows. The mean chloride concentration at these stations was 6.9 $mg.L^{-1}$ over the course of the study. This was higher than the mean values of 5.0 and 4.7 $mg.L^{-1}$ measured in 1972 and 1976. There was some increase in chloride concentrations in Sturgeon Lake over 10 years.

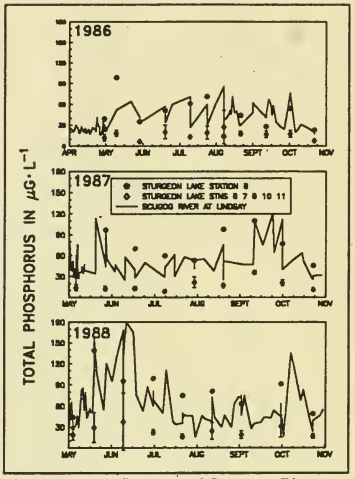

Figure 27: Influence of Scugog River on phosphorus concentrations at Sturgeon Lake Station 8.

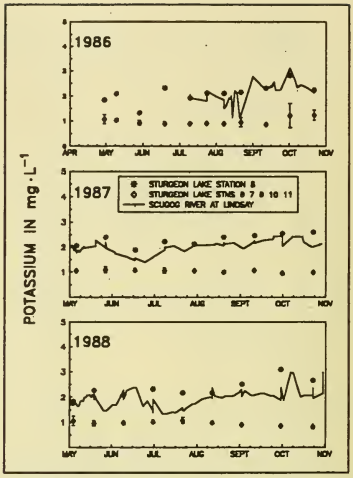

Figure 28: Influence of Scugog River on potassium concentrations at Sturgeon Lake Station 8.

Trophic Status Indicators

Table 27 presents an analysis of variance table showing the significance of 3 treatments, station, year and month of study on trophic status indicators in Sturgeon Lake. Treatments which were significant are marked with "*" and tests for significant differences between means for these treatments are given in Table 28.

Analysis of variance showed significant differences in concentrations of chlorophyll a and total phosphorus (TP) and in Secchi depth between stations in Sturgeon Lake (Table 27). This between-station variance was controlled by poor water quality at Station 8 offshore of the Lindsay sewage lagoons and the mouth of the Scugog River (Table 28). Total phosphorus concentrations averaged 66.6 $\mu g \cdot L^{-1}$ at Station 8, compared to 16.8-24.9 $\mu g \cdot L^{-1}$ at the other five water quality stations over the entire study period (Figure 30). This phosphorus enrichment produced higher chlorophyll a concentrations (30.7 vs 5.3-11.0 $\mu g \cdot L^{-1}$, Figure 30) and lower water clarity (Secchi depth = 0.7 vs 2.2-2.9 m; Table 28, Figure 31) at Station 8.

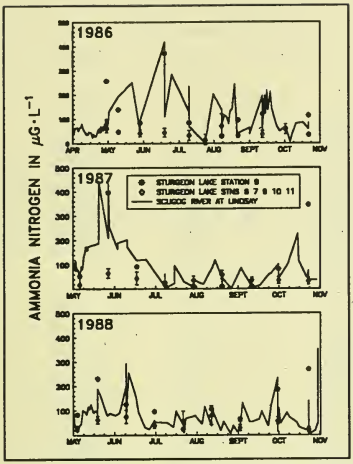

Figure 29: Influence of Scugog River on NH_4 concentrations at Sturgeon Lake Station 8.

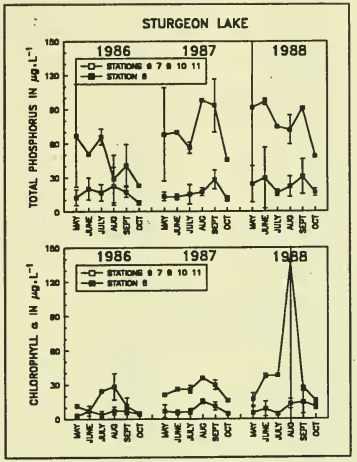

Figure 30: Phosphorus and chlorophyll "a" concentrations in Sturgeon Lake.

Chlorophyll a concentration in Sturgeon Lake did not change between years or months (Table 27) with the exception of high values at Station 8 in August of 1988 (Figure 30). Total phosphorus concentration was significantly higher in Sturgeon Lake in 1988 (mean = 33.1 ± 28.1 $\mu g \cdot L^{-1}$, Table 28) than in 1986 or 1987 (mean = 21.9 and 26.7 $\mu g \cdot L^{-1}$). The lowest TP concentrations in all years were recorded in October (16.4 ± 2.3 $\mu g \cdot L^{-1}$) and TP concentrations ranged from 24.2 ± 19.8 to 33.0 ± 2.9 $\mu g \cdot L^{-1}$ between May and September of all years (Table 28, Figure 30, Figure 6.37).

Water clarity in Sturgeon Lake was significantly greater in 1986 than in 1987 and 1988 (2.7 m vs. 2.1-2.2 m, Table 28). Monthly differences were not consistent from year to year. Water clarity was greatest in October of 1987 and 1988 compared to May and July in 1986 (Figure 31). Chlorophyll a concentration had the expected strong but variable influence on water clarity (Figure 31). There was also a weak relationship between concentrations of total phosphorus and chlorophyll a which were measured at the six in-lake stations during the summer months (R^2 = 0.47, Figure 32). Mean monthly values of the N:P ratio recorded at the outflow to Sturgeon Lake ranged from 74:1 to 1049:1 when calculated on a molar basis (Table 32), showing that Sturgeon Lake was phosphorus limited (Hutchinson 1957).

Table 27: Analysis of variance of trophic status indicators in Sturgeon Lake.

Source	SS	Df	MS	F-Ratio	P(F)
A) Chlorophyll a (Corrected)					
Grand Mean	10660.62	1	10660.62	40.9	0.0000*
Month	2916.170	5	583.2341	2.2	0.0622
Year	1291.621	2	645.8107	2.5	0.0925
Year.Month	1398.714	10	139.8714	0.54	0.8570
Stn	5285.023	5	1057.005	4.1	0.0031*
Stn.Month	4237.443	25	169.4977	0.65	0.8812
Stn.Year	1789.958	10	178.9958	0.69	0.7322
Stn.Year.Mont h	5645.057	50	112.9011	0.43	0.9986
Error	15372.18	59	260.5454		
B) Chlorophyll a (Total)					
Grand Mean	18206.93	1	18209.63	49.0	0.0000*
Month	3765.786	5	753.1572	2.03	0.0879
Year	1847.598	2	923.7988	2.49	0.0919
Year.Month	1825.942	10	182.5942	0.49	0.8886
Stn	9534.604	5	1906.921	5.14	0.0006*
Stn.Month	6297.819	25	251.9128	0.68	0.8561
Stn.Year	2828.122	10	282.8122	0.76	0.6642
Stn.Year.Mont h	8148.937	50	162.9787	0.44	0.9983
Error	21534.22	58	371.2797		
C) Total Phosphorus					
Grand Mean	107715.4	1	107715.4	365.4	0.0000*
Month	3984.177	5	796.8354	2.70	0.0282*
Year	3327.843	2	1663.921	5.64	0.0056*
Year.Month	2896.945	10	289.6945	0.98	0.4675
Stn	46875.79	5	9375.158	31.8	0.0000*
Stn.Month	4327.574	25	173.1030	0.59	0.9291
Stn.Year	3796.989	10	379.6989	1.29	0.2566
Stn.Year.Month	6343.231	50	126.8646	0.43	0.9988
Error	185710.17	63	294.7645		
D) Secchi Depth					
Grand Mean	803.0194	1	803.0194	1606.3	0.0000*
Month	19.763.83	5	3.952767	7.9	0.0000*
Year	5.721298	2	2.860649	5.7	0.0055*
Year.Month	15.53281	10	1.553281	3.1	0.0033*
Stn	78.41389	5	15.68278	31.4	0.0000*
Stn.Month	14.05644	25	0.5622576	1.1	0.3492
Stn.Year	3.608272	10	0.3608272	0.72	0.7005
Stn.Year.Month	12.08250	50	0.2416500	0.48	0.9949
Error	27.49500	55	0.4999091		

Comparisons between years, stations, and months were judged significant at $p<0.05$; and are shown by *.

Table 28: Mean values for Sturgeon Lake trophic status indicators, 1986-1988.

Chl a (corrected)				Chl a (total)			Total Phosphorus			Secchi Depth		
Stn	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n
Significant effect of Station												
SN6	3.9^{A}	2.5	28	5.3^{A}	2.9	27	16.8^{A}	12.0	28	2.7^{E}	0.8	27
SN7	8.2^{A}	4.3	27	11.0^{A}	6.4	27	24.9^{A}	19.7	28	2.2^{E}	0.6	27
SN8	23.2^{B}	35.6	28	30.7^{B}	42.2	28	66.6^{B}	29.4	28	0.7^{F}	0.4	27
SN9	6.0^{A}	4.5	28	7.6^{A}	5.1	28	19.3^{A}	8.4	32	2.8^{E}	1.0	27
SN10	5.8^{A}	4.6	28	7.3^{A}	5.3	28	18.4^{A}	11.2	27	2.7^{E}	1.0	27
SN11	4.9^{A}	3.1	28	6.2^{A}	3.6	28	18.0^{A}	9.0	28	2.9^{E}	0.9	28

Significant effect of year

Year	Mean	SD	n
1986	21.9^{A}	18.1	59
1987	26.7^{A}	24.1	54
1988	33.1^{B}	28.1	58

Significant effect of Month

Month	Mean	SD	n
May	26.5^{AB}	29.3	36
Jun	33.0^{B}	29.0	25
Jul	24.2^{AB}	19.8	29
Aug	27.2^{AB}	21.4	32
Sept	32.3^{B}	23.4	31
Oct	16.4^{AC}	2.3	18

No significant effect of Year, Month or Year x Month on Chlorophyll

Significant Year + Month interactions

1986	2.7^{C}	1.1	55
May	2.7^{B}	1.1	7
Jun	2.3^{A}	0.8	6
Jul	3.4^{B}	1.5	12
Aug	2.9^{A}	1.1	12
Sept	2.1^{A}	0.5	12
Oct	2.5^{A}	0.8	6
1987	2.2^{D}	1.1	54
May	2.2^{A}	1.2	12
Jun	2.3^{A}	0.9	6
Jul	2.4^{A}	1.2	12
Aug	1.6^{A}	0.7	6
Sept	1.7^{A}	0.6	12
Oct	3.7^{B}	1.2	6
1988	2.1^{D}	1.0	54
May	2.4^{A}	1.3	12
Jun	1.8^{A}	0.9	12
Jul	2.4^{A}	1.2	6
Aug	1.8^{A}	0.7	12
Sept	1.8^{A}	0.5	6
Oct	2.7^{B}	0.6	6

Identical superscripts within a column denote comparisons which were not significantly different ($p < 0.05$). Between-station comparisons were significant for all four trophic status indicators. Monthly and yearly comparisons were significant for total phosphorus and year x month interactions were significant for Secchi depth.

Historical Trophic Status Comparison

Any interpretation of changes in Sturgeon lake water quality between 1971 and the present must be made with caution. Data available from the 1971 MOE surveys were recorded as minimum and maximum values for total phosphorus, chlorophyll a and Secchi depth (MOE, 1971) and raw data were not available. Although the equivalent data were chosen from the present study for comparison, changes could not be determined with statistical confidence. In addition, the phosphorus analytical methodology improved between 1971 and the present. In 1972, the detection limit for TP was 7 $\mu g.L^{-1}$ and precision was ± 6-11 $\mu g.L^{-1}$ (MOE, 1975). For the present study, the detection limit was 2 $\mu g.L^{-1}$ and precision was ± 24.4% (Table 4). The changes in TP concentrations reported below may not therefore be significant.

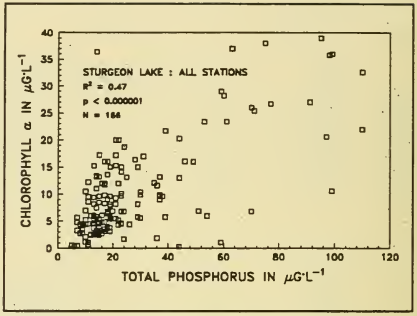

Figure 31: Relationship between phosphorus and chlorophyll a in Sturgeon Lake.

Minimum concentrations of total phosphorus dropped from 15-24 $\mu g.L^{-1}$ in 1971 to 10-17 $\mu g.L^{-1}$ in 1986-88 (Table 29). Maximum concentrations increased from 26-44 $\mu g.L^{-1}$ to 70-110 $\mu g.L^{-1}$ in the north (Fenelon Falls) arm of Sturgeon Lake between the two studies but showed no change in the northeast (Bobcaygeon) arm of the lake. The mean of all TP measurements from 1971 was 29 $\mu g.L^{-1}$ (MOE,1971) compared to 19.2 ± 12.7 in 1986-88 (Table 26)

Table 29: Comparison of trophic status indicators for Sturgeon Lake between 1971 and 1986-88.

Station Number		Total Phosphorus		Chlorophyll a		Secchi Depth	
1971	86-88	1971	86-88	1971	86-88	1971	1986-88
S7	S6	15-26	11.70	1.6-5.2	1.7-13.2	1.7-3.5	1.3-4.2
S9	S7	23-44	17-110	5.0-14	4.3-29	1.6-2.1	1.3-3.1
S8	S9	22-46	11-47	2.7-20	3.7-20	1.5-3.7	1.3-4.5
S10	S10	16-38	10-36	2.5-21	2.6-20	1.8-3.5	1.1-4.0
S11	S11	24-40	13-38	3.0-27	4.3-13.4	1.2-3.9	1.5-3.2

Minimum and maximum values are given for each parameter in $\mu g \cdot L^{-1}$ except for Secchi depth which is given in m. Where station locations were different between years the closest station is used for comparison.

Twenty years of data (246 observations) from the outflow of Sturgeon Lake suggest that water quality improved between 1971 and 1991. The mean annual TP concentration decreased by approximately 0.6 $\mu g.L^{-1}.yr^{-1}$ (Figure 33, Table 30). Between 1971 and 1978, TP concentration averaged 20-40 $\mu g.L^{-1}$; between 1979 and 1984 the annual means ranged from 25 to 35 $\mu g.L^{-1}$ and between 1985 and 1991 the annual means ranged from 12 to 22 $\mu g.L^{-1}$. The decrease was significant ($p<0.045$) but variation between samples and months produced a weak coefficient of determination ($R^2=0.02$), and changes in analytical methods do not allow a firm conclusion.

Minimum chlorophyll a concentrations showed little change between 1971 and 1986-1988 (Table 29). Maximum concentrations doubled in the north arm of the lake and were steady or decreased in the northeast arm between 1971 and 1986-88. Summer Secchi depth showed less variation in 1971, compared to 1986-88. At 4 of the 5 stations, minimum values were lower and maximums higher in 1986-88 than in 1971 (Table 29).

Higher maximum concentrations of total phosphorus and chlorophyll a, and lower minimum Secchi depths suggest that the water quality in the north arm of Sturgeon Lake deteriorated between 1971 and the present. In addition, stn 6 from the 1986-88 study was closer to the Fenelon Falls inflow than stn 6 from 1971. This suggests that a higher proportion of Precambrian shield inflow should have resulted in lower values for trophic status indicators in the present study. Higher present-day phosphorus maxima show that this was not the case.

Long-term monitoring data suggest that total phosphorus concentrations in the outflow from Sturgeon Lake decreased between 1971 and 1991. At least some of this decrease is probably associated with changes in analytical methods for phosphorus, but chlorophyll a concentrations also suggest that eutrophication has decreased in the northeast arm between 1971 and 1986-1988.

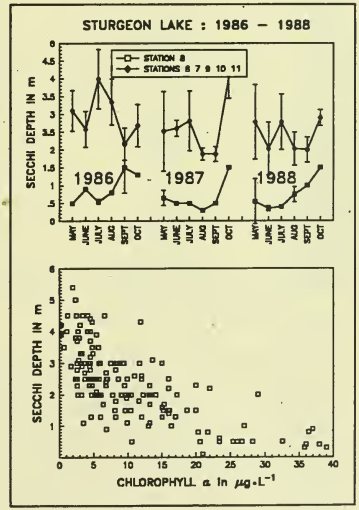

Figure 32: Secchi depth and chlorophyll a in Sturgeon Lake.

Monthly values of the N:P ratio at the Sturgeon Lake outlet at Bobcaygeon ranged from 74:1 to 1049:1 when expressed on a molar basis indicating that nitrogen limitation did not occur in Sturgeon Lake (Table 30). Late summer minima of 87-134 were well within the range of phosphorus limitation.

Table 30: Mean annual concentrations of total phosphorus ($\mu g.L^{-1}$) in the Big Bob Channel outflow of Sturgeon Lake from January 1971 to March 1991.

Year	Mean	SD	n
1971	31.8	23.5	16
1972	25.4	10.2	17
1973	27.7	8.1	12
1974	41.8	38.8	9
1975	21.3	9.0	10
1976	23.4	17.4	9
1977	22.1	7.8	9
1978	19.4	7.6	8
1979	35.2	53.1	11
1980	32.5	53.2	12
1981	35.4	37.1	12
1982	59.8	63.2	12
1983	30.2	31.7	20
1984	25.0	17.8	15
1985	18.2	9.7	13
1986	19.5	12.7	12
1987	12.6	3.9	12
1988	15.8	8.0	13
1989	15.7	8.8	10
1990	22.2	15.8	11
1991	12.0	1.0	3

Sturgeon Lake Tributary Network

A summary of water quality statistics for all streams in the Sturgeon Lake tributary network is presented in Table 31. Detailed statistics for individual streams are given in Tables 1.23 to 1.31 (App. 1). Histograms showing the frequencies of concentrations of each water quality parameter are presented in Figures 3.1 to 3.9 (App. 3). Figures 4.7 to 4.15 (App. 4) show the relationship of discharge to concentrations of total phosphorus, chloride and potassium for each stream. Figures 6.1 to 6.37 show the concentrations of total phosphorus, chloride, potassium, nitrogen and chlorophyll a measured over time at each site.

Total Phosphorus

Four distributions of measured phosphorus concentrations were seen in the Sturgeon Lake tributaries. The lowest TP concentrations were measured at the major inflow at Fenelon Falls. The three-year median value of 158 measurements was 8 $\mu g.L^{-1}$ and 88% of all measurements were <12 $\mu g.L^{-1}$. (Table 31, Figure 3.1B). The six small streams (McLaren,

Martin, Hawkers, Rutherford, Dunsford and Emily Creeks) all showed distributions different from that at Fenelon Falls. Median concentrations of total phosphorus ranged from 15 to 21 $\mu g.L^{-1}$ and over 75% of all measurements were $<30\ \mu g.L^{-1}$ (Table 31, Figure 3.1A). Hawkers Creek had the lowest total phosphorus concentration. The median value was 15 and 24% of all values were $<10\ \mu g.L^{-1}$.

The Scugog River had the lowest quality water of all tributaries. Over 50% of the 468 TP measurements exceeded 30 $\mu g.L^{-1}$, 5% exceeded 100 $\mu g.L^{-1}$ and the median value was 33 $\mu g.L^{-1}$ (Table 31, Figure 3.1B). Finally the lake outlet at Bobcaygeon reflected the dominance of the Precambrian Shield drainage entering the lake at Fenelon Falls. The median concentration measured there was 13 $\mu g.L^{-1}$, 85% of all values were <20 and all were <70 $\mu g.L^{-1}$ (Table 31, Figure 3.1B). Concentrations $>200\ \mu g.L^{-1}$ were measured in the Scugog River, Emily, Martin and Rutherford Creeks.

Table 31: Monthly mean and standard deviation of N:P ratio in Sturgeon Lake, measured at Bobcaygeon. N:P ratio = nitrate and Kjeldahl nitrogen/total phosphorus, on a molar basis.

	1986		1987		1988		1989	
Month	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Jan	- -		288	137	414	55	402	61
Feb	746	0	506	105	499	61	502	101
Mar	1049	213	803	179	649	117	601	70
Apr	599	161	901	157	798	255	892	155
May	258	52	230	88	431	114	562	238
June	140	62	74	27	127	40	-	-
July	155	68	142	65	101	20	-	-
Aug	87	18	121	41	120	22	-	-
Sept	134	79	100	18	101	21	-	-
Oct	176	60	122	6	96	7	-	-
Nov	222	58	171	28	159	60	-	-
Dec	339	123	320	97	366	54	-	-

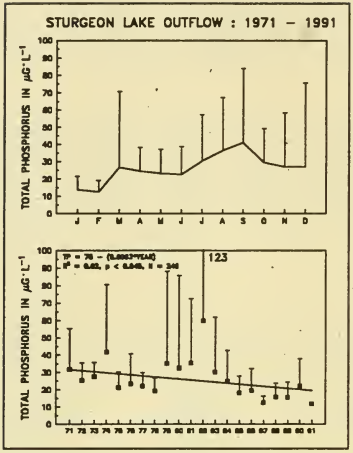

Figure 33: Monthly and annual means of TP concentrations in the Big Bob Channel, 1971-91.

The inflow to Sturgeon Lake at Fenelon Falls reflected the influence of large upstream lakes in minimizing variable phosphorus inputs. There was no relationship between phosphorus concentration and discharge (Figure 4.14) and apart from lower concentrations between October and December (Figure 6.8) no seasonality to phosphorus concentrations. High concentrations of TP were measured at all levels of discharge of the Scugog River. Concentrations were lowest in the winter (October-March, Figure 6.7) and rose gradually between March and May. The gradual response to the spring freshet may reflect the moderating influence of Lake Scugog. Concentrations declined in the summer but rose again in the autumn.

McLaren, Rutherford, Hawkers and Martin Creeks all showed no relationship between discharge and TP concentration (Figures 4.7 to 4.10). Low concentrations in all creeks occurred between October and February and all creeks but McLaren responded to the spring freshet with high concentrations (Figures 6.2 to 6.4). In McLaren Creek, the highest concentrations were recorded during the summer drought period in 1986 and 1987 (Figure 6.1). Summer peaks were also observed in the other four creeks but did not appear to be related to summer storms.

In Dunsford Creek, the baseline of lowest measured phosphorus concentration increased with flow but maximum values did not change (Figure 4.1). Concentrations were lowest between October and January with any high values apparently corresponding to increased flow. Although concentrations peaked in the spring freshet, high values were also observed in the summer (Figure 6.5). The baseline of low concentration in Emily Creek increased from 5-10 $\mu g.L^{-1}$ at low flow to 20 at higher flow but extremely high values were confined to low flow only (Figure 6.6). The only spring peak was observed in 1989; in other years values were equally high in the summer. Phosphorus concentrations at this site responded as much to the influence of Sturgeon Lake as to terrestrial influences. The unique concentration/discharge pattern shown in Figure 4.12 suggests mixing of Emily Creek with Sturgeon Lake water, perhaps by wind or seiche action moving lake water into the large complex of marshes at the mouth of Emily Creek.

Table 32: Water quality summary for all Sturgeon Lake tributary streams: 1986-88.

	Total Phosphorus				Ammonia				Kjeldahl Nitrogen				Nitrate			
	n	x̄	SD	med.	n	x̄	SD	med.	n	x̄	SD	med.	n	x̄	SD	med
McLaren	278	25	19	19	281	51	55	32	281	700	230	670	280	979	707	86
Rutherford	301	23	22	18	305	33	52	18	305	722	207	710	305	1571	1280	110
Hawkers	382	20	14	15	389	60	81	26	389	517	167	490	389	161	137	115
Martin	361	27	26	18	367	29	44	18	368	419	206	370	367	263	217	155
Dunsford	445	22	15	19	450	99	144	38	451	853	301	780	450	199	255	105
Emily	606	24	20	21	612	176	226	64	611	873	517	780	612	141	189	40
Fenelon Falls	158	8	4	8	161	37	20	32	159	304	53	310	161	83	62	65
Scugog R.	468	41	29	33	472	109	100	77	473	898	245	875	470	483	464	380
Bobcaygeon	260	15	9	13	261	63	47	50	260	423	103	410	261	192	152	165

	Sodium				Chloride				Potassium			
	n	x̄	SD	med.	n	x̄	SD	med.	n	x̄	SD	med.
McLaren	288	6.7	2.8	5.8	282	7.9	5.1	14.1	229	2.0	0.7	1.9
Rutherford	304	5.2	2.8	4.3	305	11.9	7.5	8.8	246	1.6	0.6	1.4
Hawkers	390	2.1	0.9	1.9	390	4.4	2.0	3.8	320	1.1	0.3	1.0
Martin	370	3.6	0.9	3.6	369	7.8	2.7	7.1	302	0.9	0.3	0.9
Dunsford	449	11.1	7.8	8.8	445	27.0	17.5	21.2	451	1.8	0.6	1.7
Emily	612	5.5	2.6	5.2	613	14.2	7.2	12.8	532	1.6	0.7	1.6
Fenelon Falls	160	2.5	0.2	2.5	161	4.2	0.5	4.1	137	0.8	0.1	0.8
Scugog R.	468	9.1	2.4	8.8	470	18.7	4.5	18.0	393	2.1	0.4	2.1
Bobcaygeon	253	4.2	0.7	4.0	253	7.7	1.6	7.1	197	1.1	0.2	1.1

All concentrations in $\mu g \cdot L^{-1}$ except Na, Cl and K ($mg \cdot L^{-1}$). Med. = median.

Little seasonality was apparent in TP concentrations measured at the Sturgeon Lake outlet at Bobcaygeon. Concentrations were lowest between October and February, were slightly higher in September, peaked in the April 1986 freshet but showed no pattern otherwise (Figure 6.9). Concentration had little relationship with discharge except that all 7 concentrations >35 $\mu g.L^{-1}$ were recorded at the lower 25% of flow (Figure 4.15).

Chloride

Sturgeon Lake tributary streams had very different ranges and distributions in chloride concentration. Hawkers Creek had the lowest chloride levels with over 50% of all measurements between 2 and 4 $mg.L^{-1}$ (Figure 3.2A) and 80% <6 $mg.L^{-1}$. The median chloride concentration in Hawkers Creek (3.8 $mg.L^{-1}$) was similar to that in the Precambrian Shield inflow at Fenelon Falls (4.1 $mg.L^{-1}$, Table 31). Chloride concentrations in Martin Creek had a tight distribution around a median value of 7.1 but values over 20 $mg.L^{-1}$ were also recorded (Figure 3.2A). The distribution of chloride concentrations in Martin Creek most closely resembled that of the Sturgeon Lake outflow at Bobcaygeon (median = 7.1, >80% of measurements between 4 and 10 $mg.^{-1}$, Figure 3.2B). In Rutherford Creek chloride concentrations were higher (median = 8.8) and spread more evenly over a wide range with

>12 mg.L^{-1} (Figure 3.2A) and Dunsford Creek was extremely high in chloride concentration (median = 21.2 mg.L^{-1} Table 31). Chloride concentrations in the Scugog River were high and distributed evenly at concentrations >14 mg.L^{-1} (Figure 3.2B).

All small streams showed a clear pattern of near exponential decrease in chloride concentration as discharge increased, suggesting dilution of a steady supply of chloride in their watersheds (Figures 4.7 to 4.12). In contrast, the Scugog River and Fenelon Falls inflow showed an even distribution of chloride concentrations at all discharge values (Figures 4.13, 4.14). The baseline of minimum concentration increased approximately 1 mg.L^{-1} between low and high flow at the Bobcaygeon outlet of Sturgeon Lake (Figure 4.15).

The seasonal distribution of chloride concentrations in McLaren, Dunsford, Rutherford, Martin and Hawkers Creeks reflected their concentration/discharge relationships. Concentrations increased as flows dropped between June and September and then decreased with the onset of autumn rains (Figures 6.10 to 6.14). Concentrations rose over the winter months and were diluted quickly during the spring freshet.

The lake influence removed most of the seasonality in concentration measured at the mouth of Emily Creek so that only a slight drop in spring was observed, (Figure 6.15). The Scugog River also reflected the influence of Lake Scugog in reducing seasonal fluctuations in Cl concentration so that only a slight spring decrease was observed (Figure 6.16). No pattern was seen in the Fenelon Falls inflow (Figure 6.17) and only a tendency for higher concentrations in February to April was seen at the Bobcaygeon outlet (Figure 6.18).

The tendency for chloride concentrations in Sturgeon Lake streams to increase in both summer and winter suggests that chloride concentrations were driven as much by hydrology and natural factors as they were by human influence such as road salt applications.

All Sturgeon Lake inflow streams showed increased concentrations of Na and Cl over the three years of the study. These increases ranged from 0.5 mg.L^{-1} Cl at the Fenelon Falls inflow to 17 mg.L^{-1} at the Dunsford Creek site (Table 32). In nearly all cases, significant increases were recorded between each year. These increases likely reflect hydrologic differences between years. Figures 4.7 to 4.12 show that chloride concentrations decreased exponentially with increasing flow in all but the Fenelon Falls and Scugog River sites. Discharge from all streams was greatest in the first year of the study (Figure 80, Hutchinson et al. 1993a) and decreased thereafter. Increased chloride concentrations were a function of decreased discharge. Expressing the annual changes in the chloride concentrations on a molar basis (ueq/L, Table 33) showed that, on average, Cl increased by twice as much as Na. This suggests that road salt (NaCl) applications and hydrology were not the only source of increased chloride. The use of $CaCl_2$ as a dust suppressant in the Sturgeon Lake watershed may also have contributed to the increases.

Table 33: Changes in concentrations of chloride and sodium in Sturgeon Lake tributary streams between 1986 and 1988.

		CHLORIDE			SODIUM			ANNUAL CHANGE (ueq/L)	
Tributary	**Year**	**Mean**	**S.D.**		**Mean**	**S.D**		**Chloride**	**Sodium**
Fenelon Falls	1986	3.92	0.37	A	2.37	0.12	A		
(Inflow)	1987	4.20	0.27	B	2.59	0.13	B	8.0	9.3
	1988	4.50	0.53	C	2.65	0.15	C	8.4	2.7
Bobcaygeon	1986	8.14	1.87	A	4.35	0.75	A		
(Outflow)	1987	7.35	1.15	B	4.09	0.55	B	-22.1	-11.5
	1988	7.50	1.72	B	3.95	0.66	B	4.2	-6.2
Scugog River	1986	17.52	2.82	A	8.49	1.80	A		
	1987	18.13	4.37	A	8.98	2.54	A	20.8	22.2
	1988	22.78	3.67	B	10.65	1.81	B	130	72.2
Emily Creek	1986	12.72	4.35	A	5.26	1.76	A		
	1987	13.38	3.11	A	5.45	1.13	A	18.6	8.3
	1988	18.46	11.16	B	6.43	4.21	B	143	42.8
Dunsford Cr	1986	17.38	4.56	A	7.62	2.02	A		
	1987	26.75	15.55	B	11.10	6.66	B	259	149
	1988	34.69	21.47	C	13.80	10.22	C	250	130
McLaren Cr	1986	13.17	3.37	A	5.8	1.32	A		
	1987	19.50	6.28	B	7.89	2.63	B	163	96.2
	1988	23.44	9.61	C	8.42	3.31	B	165	43.2
Martin Cr	1986	6.48	0.81	A	3.28	0.48	A		
	1987	7.67	1.52	B	3.66	0.67	B	33.5	16.5
	1988	10.69	3.21	C	4.22	1.0	C	86.5	24.7
Hawkers Cr	1986	3.69	1.26	A	1.97	0.64	A		
	1987	4.37	1.41	B	2.17	0.78	BA	19.1	8.7
	1988	6.00	2.59	C	2.37	1.15	B	45.8	8.7
Rutherford Cr	1986	8.68	3.90	A	4.18	1.67	A		
	1987	12.87	6.66	B	5.79	2.89	B	119	69.9
	1988	18.36	8.97	C	6.91	3.27	C	155	48.8

All concentrations given as annual mean (1 standard deviation) for each hydrologic year (June 1-May 31) of the study. Identical letters denote means which were not significantly different ($p<0.05$).

The exception to this pattern was at the outflow from Sturgeon Lake where Na and Cl decreased as discharge dropped over the study (Table 33). Figure 4.15 shows that chloride concentrations decreased with increasing discharge from the Big Bob Channel so that lower flows in years 2 and 3 produced lower chloride concentrations.

Potassium

Hawkers Creek, Martin Creek and the Bobcaygeon outflow all showed fairly tight distributions of potassium concentration around median values of 1.02, 0.86 and 1.06 $mg.L^{-1}$, respectively (Figure 3.4A,B). In Dunsford, McLaren and Rutherford Creeks the potassium concentrations were distributed more widely and frequently exceeded 2.0 $mg.L^{-1}$ (Figure 3.4A). The median concentration at the mouth of Emily Creek was 1.63 $mg.L^{-1}$ but individual values ranged from <0.2 to >2.0 $mg.L^{-1}$ (Figure 3.4A). Potassium concentrations were highest and lowest at the Scugog River and Fenelon Falls sites respectively (Figure 3.4B).

Few streams showed a clear relationship between discharge and potassium concentration. No pattern at all was observed for Hawkers Creek, the Scugog River, the inlet at Fenelon Falls or the outlet at Bobcaygeon (Figures 4.9, 4.13 to 4.15). In McLaren, Rutherford and Martin Creeks the baseline of lowest measured concentration increased with discharge but high concentrations were observed at all flows (Figures 4.7, 4.8, 4.10). In Dunsford Creek high potassium concentrations were measured only in the lower 10% of observed discharge values. Emily Creek had the most complex pattern. Potassium concentrations ranged from 0.2 to 4.4 $mg.L^{-1}$ in thelower 10% of the range of flow butconverged to a range of 1.4-1.8 $mg.L^{-1}$ at flows > 4 $m^3.s^{-1}$ (Figure 4.12). The Emily Creek sampling site was located at the end of a long bay of Sturgeon Lake and so water chemistry was as affected by wind and seiche action from the lake as by the Emily Creek watershed during periods of low flow. The median potassium concentration at Station 10 off the mouth of Emily Creek in Sturgeon Lake, was 1.0 $mg.L^{-1}$ (Table 1.30). Concentrations <1.4 $mg.L^{-1}$ at the mouth of Emily Creek were likely related to lake influence and so the Emily Creek watershed diluted potassium inputs such that high concentrations were only found at low flows of the creek.

Seasonal patterns of potassium concentration were similar in the small streams. McLaren, Rutherford, Hawkers, Martin and Dunsford Creeks all showed increasing concentrations between June and September and declines between October and February. Concentrations rose during the early stages of snow melt and spring rains but decreased quickly thereafter (Figures 6.19 to 6.23). Little seasonal effects were seen in the Scugog River or the Fenelon Falls inflow aside from a small tendency for dilution by the freshet (Figures 6.25, 6.26). Potassium concentrations in Emily Creek showed the influence of aquatic vegetation at the creek mouth and upstream. Concentrations declined during the May-September growth period, increased again as aquatic plants died off (Figure 6.24), stayed steady until the spring freshet and then showed the pattern of quick increase and decrease seen in the smaller streams. At the outlet at Bobcaygeon some macrophyte growth could be inferred from the small decrease in concentration over the summer and increase in mid-autumn. Small changes were also observed during the spring freshet (Figure 6.27).

Nitrogen

Martin and Rutherford Creeks had similar distributions of ammonia. Median concentrations were 18 $\mu g.L^{-1}$ in each stream and 80% of all measurements were <40 $\mu g.L^{-1}$ (Table 31, Figure 3.5A). Median concentrations in Hawkers, McLaren and Dunsford Creeks ranged from 26 to 38 $\mu g.L^{-1}$ but over 10% of the values from Hawkers and Dunsford Creeks exceeded 200 $\mu g.L^{-1}$ (Table 31, Figure 3.5A). Ammonia concentrations were high at the mouth of Emily Creek. High levels in Dunsford Creek (a tributary), observations of sewage disposal on fields adjacent to Dunsford Creek and of drainage from a farm upstream of the Hawkers Creek site suggest that watershed activities were important contributors to the observed high values. Over 20% of all Emily Creek measurements exceeded 200 $\mu g.L^{-1}$ compared to 3% at the Bobcaygeon Lake outlet (Figure 3.5B). The Scugog River had a median ammonia concentration of 77 $\mu g.L^{-1}$ and 15% of all measurements exceeded 200 $\mu g.L^{-1}$ (Table 31, Figure 3.5B).

McLaren and Rutherford Creeks were highly enriched with nitrates; median values of 845 and 1190 $\mu g.L^{-1}$ in these creeks were 3-20 times higher than those in the other streams (Table 31). Over 50% of all measurements from these streams exceeded 1.0 $mg.L^{-1}$ compared to the 30-62% which were <0.1 $mg.L^{-1}$ in all other streams (Figure 3.7A). Ratios of nitrate to Kjeldahl nitrogen exceeded 1 only in McLaren and Rutherford Creeks. Emily was the only creek in which the nitrate/ammonia ratio consistently decreased to 1:1, indicating agricultural runoff (Wetzel 1975). Ammonia concentrations frequently exceeded nitrate concentrations in the winter months indicating that nitrate uptake by plant growth was not the reason for the high ratio (Figure 6.33). Nitrate concentrations always exceeded ammonia concentrations in McLaren, Rutherford and Martin Creeks suggesting that these creeks were typical of unpolluted streams draining calcareous soils (Wetzel 1975, Figures 6.25, 6.29, 6.31). In Hawkers and Dunsford Creeks nitrate:ammonia ratios suggested that agricultural runoff was a problem in winter months and during the freshet. Nitrate to ammonia ratios also suggested the presence of late summer problems in Dunsford Creek (Figure 6.32). Although ammonia frequently exceeded nitrate in the summer months in the Scugog River, the Fenelon Falls inflow and Bobcaygeon outflow, the pattern was likely related to nitrate consumption by plant growth. Ammonia levels were steady year-round but nitrate levels dropped in the summer and increased in the autumn (Figures 6.35 to 6.36).

The influence of terrestrial and aquatic plants on nitrogen metabolism was apparent in the seasonal distribution of nitrate in all streams. Nitrates were lowest in the summer and increased over the autumn to winter maxima as plant growth ceased. High winter concentrations were diluted during the spring freshet and the spring growth of plants maintained these low levels. The only major differences between streams were in the magnitude of the difference between high and low values (Figures 6.28 to 6.36).

Kjeldahl nitrogen concentrations showed no seasonal trends except some dilution during the spring freshet in the smaller streams. This dilution was not observed in the Scugog River, or the inflow and outflow sites.

Three seasonal patterns in ammonia concentration were observed among the Sturgeon Lake tributaries. Neither the inflow nor the outflow showed any seasonality, other than slightly reduced concentrations during the spring freshet (Figures 6.35, 6.36). Martin, Rutherford and McLaren Creeks and the Scugog River had highly variable ammonia concentrations year round but tended to higher concentrations in the winter and sudden drops during the spring freshet (Figures 6.28, 6.29, 6.31). Emily, Dunsford and Hawkers Creeks all showed little within-season variability, low summer and high winter concentrations (Figures 6.30, 6.32, 6.33).

SUMMARY AND CONCLUSIONS

Rice Lake

The shallow depth and exposure of Rice and Sturgeon lakes to prevailing winds prevents significant thermal stratification of their water masses so that hypolimnetic anoxia is not associated with their enriched status. Dissolved oxygen concentrations of <5.0 mg.L^{-1} in deeper waters and temporary anoxia in late summer suggest that oxygen demand would produce anoxia if the lakes were deeper. Anoxia does not develop under the ice except occasionally in isolated bays such as McGregor Bay (Lois Deacon, MNR Kawartha Lakes Fisheries Assessment Unit, pers. comm.).

Chloride concentrations in Rice Lake increased from approx. 6 mg.L^{-1} in 1972 to 9 mg.L^{-1} in 1988. Smaller changes in sodium concentrations were observed. These increases reflect increased loading from activities such as road salting within the watershed or lower runoff and discharge to the lake between 1972 and 1986-1988. Significant increases in Na and Cl levels in Rice Lake and its major tributary streams between 1986 and 1988 appeared to be entirely related to decreased discharge accompanying lower rainfall in the latter part of the study. Only 128 mm of rain fell in the summer of 1988, for example, compared to 260 mm in the summer of 1986.

Chloride concentrations in Sturgeon Lake increased from about 5 mg.L^{-1} in 1972 to 7 mg.L^{-1} in 1988. Chloride concentration in tributary streams and at station 8 in the lake increased between 1986 and 1988 but concentrations in the outflow at Bobcaygeon decreased over the same three years. These changes also appeared to be driven by changes in discharge in the watershed.

Water quality in Rice Lake has improved over the last 15 years. Average concentrations of total phosphorus and summer maxima decreased between 1971 and

the present and the degree of phosphorus limitation, as inferred from the N:P ratio at the outflow, decreased. Water clarity improved from a mean of 1.25m to 1.75 m but most of this improvement was confined to the early summer period before high algal growth. Concentrations of chlorophyll a appeared to increase, but decreases in TP concentration, and changes in the N:P ratio suggest that the algal community shifted dominance from blue green to green algae with subsequent increases in chlorophyll a.

The water quality of Rice Lake was poorest at the west end of the lake. The mean ice-free TP concentration was 33.4 $\mu g.L^{-1}$ near Bewdley but only 25.7 $\mu g.L^{-1}$ near Hastings. Summer maximum concentrations of 39-50 $\mu g.L^{-1}$ TP produced severe late summer algae blooms. Chlorophyll a values of 34-57 $\mu g.L^{-1}$ were seen in late summer compared to 5-12 $\mu g.L^{-1}$ in early summer.

Secchi depth in Rice Lake ranged from 0.8m in September to 2.5m in May and June. Concentrations of chlorophyll a, Kjeldahl and ammonia nitrogen and potassium all tracked seasonal changes in primary production in Rice Lake as they all increased from low levels in May to maxima in August and September.

Potassium concentrations in Rice Lake were very closely tied to growth and senescence of Potamogeton crispus, the dominant aquatic macrophyte. Potassium levels began decreasing in early spring when growth began and reached minimum levels at maximum biomass in early June. Senescence of P. crispus when the water temperature reached about 20° C produced immediate increases in potassium concentration in Rice Lake which were observable 10 days later at the outflow. Total phosphorus concentrations increased at the beginning of the dieback of P. crispus but significant increases in the water column of Rice lake were not observed until late June or early July. Soluble reactive phosphorus remained below or just above the detection limit of 0.5 $\mu g.L^{-1}$ throughout the period of senescence. The fate of the 12 tonnes of phosphorus stored in P. crispus biomass was not clearly resolved.

The magnitude of discharge of the various streams in the Rice Lake water quality network appeared to account for most of their variation in water quality. Concentrations of total phosphorus and potassium showed wide variations and had little relationship to discharge in the two small streams at Bewdley. By contrast the large streams had fewer extreme concentrations and concentrations decreased at high flows. Discharge of the Peterborough STP contributed to this pattern in the Otonabee River. Small streams showed maximum phosphorus concentrations during the spring freshet but larger streams often showed a second peak in late summer. Chloride concentrations were controlled by discharge in streams, with higher concentrations occurring during drier years. Seasonal patterns showed high chloride concentrations in winter associated with road salt application and dilution during the spring freshet. Maximum values were measured during low flow in the summer.

Two sets of observations suggest that agricultural activities in the Rice Lake watershed are detrimental to water quality. The highest and most variable concentrations of total phosphorus, nitrate and ammonia were recorded in the Bewdley South stream, which drained a watershed which was 93% agricultural. Nitrate:ammonia ratios were close to 1 during winter months and the spring freshet, suggesting agricultural runoff (Wetzel 1975). In addition, high concentrations of total phosphorus, nitrates and ammonia were measured during the spring freshet in a stream which drained an area containing intensive cattle and poultry rearing operations.

Sturgeon Lake

The water quality of Sturgeon Lake was marked by distinct between-station differences. The major inflow at Fenelon Falls brought low-conductivity, low nutrient water from the Precambrian Shield into the north arm of the lake. The Scugog River drained urban and agricultural areas and fed nutrient rich water into the lake. This produced high concentrations of total phosphorus, chlorophyll a, ammonia and nitrate, and low water clarity at Station 8 near Lindsay. Although discharge from the Lindsay sewage lagoons contributes to this poor water quality, the Scugog River was also important. The limnology of Sturgeon Lake thus represents a mixing of Precambrian Shield drainage and water which has been enriched by contact with thick soils, sedimentary rock and human activities such as agriculture.

Total phosphorus concentrations at the outflow of Sturgeon Lake have decreased by approximately 0.6 $\mu g.L^{-1}$ per year since 1971 and minimum summer values are lower now than in 1971. Chlorophyll a concentrations also appear to be lower in the northeast end of the lake than in 1971. In spite of these changes, total phosphorus and chlorophyll a concentrations appear to have increased in the north end of Sturgeon Lake since 1971. Total phosphorus concentrations in Sturgeon Lake ranged from 24 to 33 $\mu g.L^{-1}$ between May and September in each of the three years of the present study and were lowest (16.4 $\mu g.L^{-1}$) in October. Total phosphorus concentrations were highest offshore of Lindsay (67 $\mu g.L^{-1}$) and this produced high chlorophyll a concentrations (31 $\mu g.L^{-1}$) and low Secchi depths (0.7m).

Aside from occasional values >200 $\mu g.L^{-1}$, total phosphorus concentrations indicated good water quality in the Fenelon Falls inflow, the Bobcaygeon outflow and the small tributary streams of Sturgeon Lake. The Scugog River had very poor water quality. Over 50% of all total phosphorus measurements exceeded the provincial guideline of 30 $\mu g.L^{-1}$ for streams and rivers. Agricultural runoff and sewage disposal produced frequent high ammonia concentrations in the Scugog River, Emily, Hawkers and Dunsford Creeks. Nitrate levels in McLaren and Rutherford Creeks were 3-20 times higher than in all other streams and the seasonal distribution of nitrate concentrations in all streams reflected seasonal cycles of terrestrial vegetation growth. Chloride

concentrations appeared to be most influenced by hydrologic characteristics as concentrations in all streams were highest in dry years.

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Ms. Kathy Hooper	Bewdley South and Bewdley North
Mr. Jim Forde	Ouse River
Mr. Murray Black	Indian River
Mr. Roy Legassicke	Otonabee River
Mr. Steve Wright	Trent River
Mr. Brent Kaltwasser	Trent River
Reed and Loretta Clark	Scugog River
Mr. Harold Snider	McLaren Creek
Mr. Duncan Walls	Rutherford Creek
Mrs. Vivian Wilson	Martin and Hawkers Creeks
Mr. Ken Geary	Emily and Dunsford Creeks
Mr. Bob Brown	Big Bob Channel at Bobcaygeon
Mr. Tim Goodison	Fenelon Falls

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APPENDIX 1.0

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		Station 33		Station 34		Station 35		Station 36	
	(m)	Temp	O2	Temp	O2	Temp	O2	Temp	O2
860429	0	13.0	13.4	15.0	12.8				
	1	13.0	13.4	15.0	12.8				
	2	13.0	13.4	15.0	12.8				
	3	13.0	13.4	15.0	12.8				
	4	13.0	13.4	15.0	12.8				
	5	13.0	13.4						
860505	0	9.5	11.6	11.5	12.8	11.1	12.9	12.3	13.0
	1	9.5	11.6	11.5	12.8	11.2	12.9	12.2	13.1
	2	9.6	11.8	11.4	12.6	11.2	12.9	12.2	13.1
	3	9.6	11.8	11.0	12.4	11.1	12.9	12.0	13.1
	4	9.6	11.8	11.0	12.3	11.1	12.9	12.0	13.1
	5	9.6	11.8			11.0	12.9	12.0	13.0
	6	9.6	11.8			11.0	12.5	11.9	13.0
	7							11.9	12.6
	8							11.9	12.5
860527	0	19.9		19.0		19.0		20.3	
	1	18.5	9.4	19.0	8.4	19.0	11.0	19.5	
	2	16.9		18.5		19.0		19.1	
	3	16.5		16.8	9.4	16.9		18.1	
	4	16.3		16.2				17.7	
	0					16.7	7.8	17.4	
	6							17.2	
	7							16.9	
	8							16.9	6.6
860610	0	18.1	8.0	19.5	8.0	18.3	8.0	19.5	8.0
	1	18.1	8.0	19.1	8.0	18.3	8.0	19.5	8.0
	2	18.0	8.0	17.9	7.8	18.0	8.0	19.1	8.0
	3	17.0	7.4	17.5	6.9	17.6	8.0	18.8	8.1
	4	17.0	7.3	17.2	4.5	17.4	7.9	18.3	7.9
	5	16.9	7.0			17.4	7.8	17.9	7.6
	6					17.0	7.3	17.6	7.3
	7					16.8	6.9	17.2	7.1
	8							17.1	6.9
860617	0	18.0	7.7	18.5	7.7	18.3	7.8	18.0	7.4
	1	18.0	7.8	18.5	7.6	18.2	7.7	18.0	7.4
	2	18.0	7.8	18.5	7.6	18.2	7.7	18.0	7.4
	3	18.0	7.8	18.5	7.6	18.2	7.7	18.0	7.4
	4	18.0	7.8	18.5	7.4	18.2	7.7	18.0	7.4
	5	18.0	7.8			18.2	7.7	18.0	7.4

Table 1.1. Temperature (^{o}C) and dissolved oxygen ($mg.L^{-1}$) measured at four stations on Rice Lake during the 1986 ice-free period.

		Station 33		Station 34		Station 35		Station 36	
	(m)	Temp	O2	Temp	O2	Temp	O2	Temp	O2
860624	0	19.0	7.9	20.1	7.5	19.9	7.6	19.9	7.6
	1	19.5	7.9	20.0	7.4	19.9	7.6	19.9	7.6
	2	19.5	7.9	20.0	7.4	19.9	7.6	19.9	7.6
	3	19.0	7.9	20.1	7.3	19.9	7.6	19.9	7.6
	4	19.0	7.9	20.1	7.3	19.9	7.6	19.9	7.6
	5	18.9	7.8			19.9	7.6	19.9	7.6
	6							19.9	7.5
860708	0	22.3	7.5	22.5	7.5	22.1	7.8	22.1	7.9
	1	22.3	7.5	22.5	7.5	22.1	7.9	22.1	7.9
	2	22.2	7.5	22.6	7.5	22.1	7.9		
	3	22.2	7.5	22.6	7.5	22.1	7.9	22.1	7.9
	4			22.5	7.4	22.1	7.9	22.0	7.9
	0					22.1	7.9	22.0	7.9
	6					22.0	7.7	21.5	7.7
	7					21.5	7.1		
860722	0	23.9	7.9	25.0	8.0	24.0	7.8	23.9	7.9
	1	23.9	7.9	24.8	8.0	24.0	7.9	23.9	7.9
	2	23.6	5.6	23.9	7.9	23.9	7.9	23.9	8.0
	3	22.8	5.4	23.5	7.7	23.3	7.9	23.9	8.8
	4			23.2	6.3	23.0	7.7	23.3	8.1
	5					23.0	7.7	23.5	7.8
	6					22.9	5.6	23.2	7.0
	7					22.3	5.0	22.9	5.3
860805	0	23.9	8.9	23.9	8.3	22.2	7.0	23.5	8.7
	1	23.9	8.9	23.5	8.5	22.2	7.4	23.5	8.7
	2	23.9	9.2	23.5	8.7	22.2	7.8	23.5	8.9
	3	23.7	9.0	23.5	8.8	22.1	8.2	23.3	8.7
	4	23.5	8.6	23.5	8.8	22.1	8.1	23.0	8.5
	5	23.3	7.8			22.1	7.7	23.0	6.9
	6	23.2	7.2			22.0	7.6	23.0	5.5
	7							22.8	4.2

Table 1.1. cont'd

		Station 33		Station 34		Station 35		Station 36	
	(m)	Temp	O2	Temp	O2	Temp	O2	Temp	O2
860819	0	23.2	9.3	23.4	8.3	23.0	8.2	23.0	8.5
	1	23.0	9.3	23.2	8.4	23.0	8.2	23.0	8.6
	2	22.5	8.3	23.0	8.3	23.0	8.1	23.0	8.1
	3	22.3	7.8	22.8	7.9	22.8	7.7	22.7	8.1
	4	22.2	7.3	22.6	7.2	22.5	7.6	22.6	7.1
	5	22.0	7.2			22.5	7.4	22.6	6.9
	6							22.5	6.1
	7							22.0	3.7
860909	0	17.4	10.2	17.7	10.6	17.3	9.7	17.2	10.0
	1	17.3	10.2	17.7	10.6	17.3	9.7	17.2	9.9
	2	17.3	10.3	17.4	10.5	17.3	9.7	17.0	9.9
	3	17.3	10.2	17.0	10.4	17.3	9.7	17.0	9.9
	4	17.3	10.2			17.2	9.8	17.0	9.9
	0	17.0	10.2			17.1	9.8	17.0	9.9
	6					17.0	9.7	17.0	9.9
861021	0	9.8	9.0	10.1	9.0	10.0	9.5	10.0	9.7
	1	9.8	9.1	10.1	9.6	10.0	9.5	10.0	9.7
	2	9.5	9.1	10.1	9.6	10.0	9.5	10.0	9.8
	3	9.5	9.1	10.1	9.6	9.9	9.5	10.0	9.7
	4			10.1	9.6	9.4	9.5	10.0	9.8
	5					9.9	9.6	10.0	9.7
	6					9.9	9.5		

Table 1.1. cont'd

		Station 33		Station 34		Station 35		Station 36	
	(m)	Temp	O2	Temp	O2	Temp	O2	Temp	O2
870506	0	12.5	10.6	13.5	11.4	13.0	10.4	12.5	10.4
	1	12.5	10.6	13.5	11.5	13.0	10.5	12.5	10.4
	2	12.5	10.7	13.3	11.6	12.5	10.6	12.5	10.6
	3	12.5	10.7	12.3	11.6	12.5	10.7	12.0	10.8
	4	12.3	10.8			12.0	10.8	12.0	10.8
	0					12.0	10.6	12.0	10.8
	6					12.0	10.5	11.5	10.8
	7					11.5	10.4	11.5	10.4
	8							11.5	?
870528	0	18.5	8.8	19.0	9.0	18.0	8.5	18.5	8.5
	1	18.0	8.8	19.0	9.0	17.5	8.5	18.0	8.5
	2	17.0	8.8	17.5	9.1	17.5	8.5	17.5	8.4
	3	16.5	8.6	17.0	9.0	17.0	8.5	17.0	8.4
	4	16.0	7.9			17.0	8.5	17.0	8.3
	5	16.0	7.6			17.0	8.5	17.0	8.3
	6					16.5	7.7	17.0	8.3
	7							16.5	7.7
	8							16.0	7.6
870602	0	20.5	8.0	22.0	8.1	21.5	8.0	22.0	7.9
	1	20.5	8.0	22.0	8.1	21.5	8.0	22.0	7.9
	2	20.0	8.0	21.0	8.0	21.0	8.0	22.0	7.9
	3	19.5	8.0	18.5	6.0	21.0	8.0	25.0	7.9
	4	18.0	7.0			20.5	7.9	21.0	7.9
	0					20.0	6.9	21.0	7.9
	6					19.0	6.3	18.0	5.5
	7					18.0	4.5	17.0	5.5
	8							17.0	4.7
	9							17.0	4.2
870609	0	20.0	7.5	18.5	7.4	20.0	7.4	20.0	7.4
	1	20.0	7.5	18.5	7.4	20.0	7.4	25.0	7.4
	2	20.0	7.5	18.0	7.2	20.0	7.4	20.5	7.4
	3	20.0	7.5	18.0	7.2	20.0	7.4	20.5	7.2
	4			18.0	7.0	20.0	7.4	20.5	7.2
	5			18.0	7.1	20.0	7.4	20.5	7.2
	6			18.2	6.4	20.0	7.4	20.0	7.2
	7					20.0	7.4	20.0	7.2
	8								

Table 1.2. Temperature (°C) and dissolved oxygen ($mg.L^{-1}$) measured at four stations on Rice Lake during the 1987 ice-free period.

		Station 33		Station 34		Station 35		Station 36	
	(m)	Temp	O2	Temp	O2	Temp	O2	Temp	O2
870623	0	23.0	7.8	23.0	6.9	22.5	7.2	22.5	7.3
	1	23.0	7.8	22.5	6.8	22.5	7.4	22.5	7.2
	2	22.5	7.8	22.0	6.9	22.5	7.4	22.5	7.2
	3	23.0	7.7	22.0	7.0	22.0	7.4	22.0	7.2
	4	22.0	7.7			22.0	7.2	22.0	7.2
	0	21.5	6.7			22.0	7.2	22.0	7.2
	6					22.0	7.2	22.0	7.2
	7					22.0	7.0	22.0	7.1
	8							22.0	7.0
870630	0	21.5	6.0	22.0	5.9	21.0	6.0	22.0	5.8
	1	21.5	6.0	22.0	5.8	21.5	5.8	22.0	5.8
	2	22.0	5.8	22.0	5.8	21.5	5.8	22.0	5.8
	3	22.0	5.8	22.0	5.8	22.0	5.8	55.0	5.7
	4	22.0	5.8	22.0	5.7	22.0	5.8	22.0	5.7
	5	22.0	5.8					22.0	5.8
	6							22.0	5.7
	7							22.0	5.7
870708	0	25.0	7.0	25.5	7.8	24.5	7.8	24.0	7.6
	1	23.5	7.1	24.5	7.8	24.5	7.9	24.0	7.6
	2	22.5	6.9	23.5	7.8	24.0	7.8	24.0	7.6
	3	22.0	6.2	23.5	7.7	24.0	7.7	23.5	7.4
	4	22.0	4.6	23.5	7.7	24.0	7.6	23.5	7.2
	5	21.5	3.7			23.0	4.7	23.0	4.7
	6					22.0	4.7	22.0	4.9
	7					22.0	4.2	22.0	4.9
	8							21.5	3.2
870819	0	24.0	7.8	24.0	7.9	24.0	7.4	24.0	7.4
	1	24.0	7.8	24.5	7.9	24.0	7.3	24.0	7.3
	2	24.0	7.6	24.0	7.9	24.0	7.3	24.0	7.3
	3	24.0	7.5	24.0	7.6	24.0	7.2	24.0	7.3
	4	23.5	7.3			23.5	7.2	24.0	7.1
	5	23.5	6.6			23.5	6.9	24.0	7.1
	6					23.5	6.8	22.5	7.0
	7					23.5	6.7	23.5	6.7

Table 1.2. cont'd

		Station 33		Station 34		Station 35		Station 36	
	(m)	Temp	O2	Temp	O2	Temp	O2	Temp	O2
870910	0	19.0	9.5	20.5	10.4	19.0	8.8	19.0	9.3
	1	19.0	9.5	19.5	10.5	19.0	8.7	19.0	9.3
	2	19.0	9.5	19.0	10.6	19.0	8.7	19.0	9.2
	3	19.0	9.2	19.0	9.2	19.0	8.4	19.0	8.8
	4	19.0	9.2			19.0	8.3	19.0	8.7
	5	19.0	9.0			19.0	8.3	19.0	8.7
	6					19.0	8.0	19.5	5.0
	7					18.0	3.5	18.0	4.6
	8							18.0	3.0
870930	0	15.5	8.6	16.0	8.9	15.5	8.9	16.0	8.9
	1	16.0	8.6	16.0	8.9	15.5	8.9	16.0	9.0
	2	16.0	8.6	16.0	9.0	15.5	8.9	16.0	9.0
	3	16.0	8.5	16.0	9.0	15.5	8.9	16.0	8.9
	4	16.0	8.4			15.5	8.8	16.0	8.9
	5					15.5	8.8	16.0	8.9
	6					15.5	8.7	16.0	8.9
	7					15.5	8.7	16.0	8.9
871022	0	9.3	9.8	9.5	10.3	9.8	9.8	9.8	9.8
	1	9.3	9.8	9.5	10.4	9.8	9.8	9.8	9.8
	2	9.3	9.7	9.5	10.4	9.8	9.8	9.8	9.8
	3	9.2	9.7	9.5	10.4	9.8	9.8	9.8	9.8
	4	9.2	9.7			9.8	9.8	9.8	9.8
	5					9.8	9.8	9.8	9.8
	6					9.8	9.8	9.8	9.7
	7					9.8	9.8	9.8	9.7
	8					9.8	9.8	9.8	9.7

Table 1.2. cont'd

		Station 33		Station 34		Station 35		Station 36	
	(m)	Temp	O2	Temp	O2	Temp	O2	Temp	O2
880503	0	9.7	11.2	9.7	10.5	10.0	11.0	9.0	10.5
	1	9.7	11.3	9.8	10.6	10.0	11.0	9.0	10.5
	2	9.7	11.4	9.8	10.6	10.0	11.0	9.0	10.5
	3	9.7	11.4	9.7	10.6	9.5	11.0	9.0	10.5
	4	9.7	11.3			9.5	11.0	9.0	10.5
	5					9.5	11.0	9.0	10.4
	6					9.5	11.0	9.0	10.3
	7					9.5	10.9	9.0	10.1
	8							9.0	10.1
880518	0	14.2	9.7	14.5	10.0	14.8	9.9	15.0	10.0
	1	14.2	9.8	14.5	10.2	14.8	9.9	15.0	9.9
	2	14.2	9.9	14.5	10.3	14.8	9.9	14.5	9.9
	3	14.1	9.9	14.5	10.3	14.8	9.9	14.5	9.9
	4	14.0	10.0			14.8	9.9	14.5	9.9
	5					14.8	9.9	14.5	9.9
	6					14.5	9.9	14.5	9.9
	7							14.5	9.9
	8							14.5	9.9
880531	0	20.4	8.6	21.2	9.7	20.5	9.2	21.1	8.7
	1	20.3	8.6	21.3	9.7	20.2	9.1	20.6	8.9
	2	18.8	8.1	19.7	9.9	20.0	9.2	19.9	9.0
	3	18.3	7.9	19.3	9.5	19.8	9.2	19.3	9.0
	4	18.1	7.7			19.2	9.0	19.2	9.1
	5	16.8	7.1			17.7	7.7	19.0	9.1
	6							17.7	7.8
	7							16.9	7.6
880608	0	18.0	8.1	18.5	8.2	18.3	7.8	18.0	7.8
	1	17.9	8.1	18.5	8.2	18.3	7.8	18.2	7.8
	2	17.8	8.0	18.3	8.2	18.2	7.7	18.0	7.7
	3	17.6	7.8	18.1	8.0	18.1	7.6	18.0	7.7
	4	17.3	7.9			18.0	7.6	18.0	7.6
	5					18.0	7.5	17.9	7.6
	6					17.9	7.6	17.9	7.5

Table 1.3. Temperature (^{o}C) and dissolved oxygen (mg.L^{-1}) measured at four stations on Rice Lake during the 1988 ice-free period.

		Station 33		Station 34		Station 35		Station 36	
	(m)	Temp	O2	Temp	O2	Temp	O2	Temp	O2
880614	0	19.5	7.5	21.1	9.0	20.2	8.0	21.0	7.9
	1	19.3	7.5	20.8	9.0	20.0	8.0	20.8	7.9
	2	19.3	7.5	20.0	8.6	19.8	8.0	20.8	7.9
	3	19.2	7.5	19.8	8.4	19.8	8.0	20.3	7.9
	4	18.9	7.6			19.6	7.9	20.1	7.8
	5	18.5	7.4			19.5	7.9	19.8	7.7
	6					19.3	7.7	19.7	7.5
	7							19.3	7.1
880621	0	21.6	7.0	22.6	7.1	22.0	6.3	22.2	6.4
	1	21.3	7.0	22.0	7.1	22.0	6.3	22.0	6.4
	2	20.9	6.7	21.7	7.1	21.8	6.2	21.8	6.2
	3	20.7	6.4	21.5	7.1	21.7	6.3	21.6	6.1
	4	20.4	6.1			21.7	6.1	21.5	6.1
	5					21.6	5.9	21.5	6.1
	6					21.6	5.9	21.5	6.0
	7							21.4	5.9
880629	0	18.5	7.7	19.0	7.9	18.8	7.1	19.1	6.8
	1	18.8	7.5	19.0	7.8	19.1	7.0	19.2	6.7
	2	18.8	7.5	19.0	7.8	19.1	6.9	19.2	6.7
	3	18.8	7.5	19.0	7.8	19.1	7.0	19.2	6.7
	4	18.8	7.5			19.1	6.9	19.2	6.7
	5	18.8	7.5			19.1	6.9	19.2	6.7
	6					19.1	6.9	19.3	6.7
	7					19.1	6.9	19.2	6.7
880705	0	22.0	8.8	21.8	9.2	22.2	8.3	20.7	8.3
	1	20.6	8.9	21.3	9.8	21.1	8.3	20.5	8.3
	2	20.2	8.9	20.3	8.8	19.5	8.3	19.9	8.2
	3	19.5	9.1	19.3	8.0	19.2	8.2	19.6	7.8
	4	18.9	7.8			19.0	8.1	19.2	6.8
	5	18.3	7.7			18.8	6.9	18.9	6.0
	6					18.3	5.6	18.8	5.6
	7					18.2	3.5	18.7	2.9
	8							18.3	1.9

Table 1.3. cont'd

		Station 33		Station 34		Station 35		Station 36	
	(m)	Temp	O2	Temp	O2	Temp	O2	Temp	O2
880712	0	25.0	7.6	25.0	7.5	25.5	7.7	25.0	7.9
	1	25.0	7.6	50.0	7.5	25.0	7.8	25.0	7.9
	2	24.5	7.6	24.5	7.4	25.0	7.0	25.0	7.6
	3	24.0	7.3	24.0	7.1	25.0	7.0	25.0	7.6
	4	23.5	3.3	24.0	7.0	25.0	7.0	25.0	7.6
	5					25.0	7.0	25.0	7.4
	6					24.0	4.4	21.5	1.4
	7					22.0	1.4	20.0	0.4
	8							19.0	0.3
880720	0	24.0	7.7	24.3	8.0	24.8	7.6	25.0	7.9
	1	23.8	7.7	24.3	8.0	24.8	7.6	25.2	?
	2	23.8	7.5	24.3	7.9	24.8	7.6	25.0	7.8
	3	23.7	7.3	24.3	7.8	24.8	7.5	25.0	7.8
	4	23.7	7.1			24.3	5.2	24.3	4.7
	5	23.5	7.0			24.3	5.0	24.2	4.1
	6					24.1	4.2	24.1	3.2
	7					24.0	4.0	23.9	3.0
	8							23.8	2.6
880810	0	25.2	8.3	25.2	8.6	26.3	7.7	25.8	8.1
	1	25.2	8.3	25.3	8.5	25.8	7.7	25.8	8.1
	2	25.2	8.1	25.2	8.3	25.8	7.7	25.7	7.9
	3	25.2	7.9	25.2	7.9	25.8	7.6	25.7	7.8
	4	25.0	7.7			25.8	7.4	25.7	7.7
	5	25.0	7.6			25.8	7.3	25.7	7.6
	6					25.8	7.2	25.7	7.3
	7					25.8	7.2	25.6	7.2
	8							25.6	7.2
880830	0	19.7	8.1	19.3	8.3	19.4	8.3	19.7	8.6
	1	19.3	7.6	19.2	8.3	19.3	8.1	19.3	8.5
	2	19.3	7.6	18.8	7.9	19.2	7.5	19.2	7.7
	3	18.8	7.6	18.8	7.2	19.2	7.1	19.2	7.3
	4	18.7	7.2			19.2	6.6	19.2	7.3
	5	18.5	7.2			19.1	6.8	19.1	7.2
	6					19.0	6.9	19.1	6.4
	7							19.1	6.2

Table 1.3. cont'd

		Station 33		Station 34		Station 35		Station 36	
	(m)	Temp	O2	Temp	O2	Temp	O2	Temp	O2
880929	0	14.8	8.6	15.1	8.7	15.1	7.6	15.7	7.1
	1	14.9	8.6	15.1	8.7	15.2	7.6	15.7	7.0
	2	14.8	8.6	15.1	8.7	15.3	7.5	15.7	6.8
	3	14.8	8.6	15.1	8.6	15.3	7.4	15.7	6.5
	4	14.8	8.6			15.3	7.4	15.6	6.7
	5	14.8	8.6			15.3	7.3	15.5	6.8
	6					15.3	7.4	15.5	6.8
	7					15.2	7.5	15.5	6.7
	8							15.6	6.7
881019	0	9.3	9.9	9.8	9.8	9.1	8.8	9.2	9.0
	1	9.2	9.7	9.8	9.7	9.2	8.7	9.2	8.8
	2	9.2	9.6	9.7	9.6	9.1	8.7	9.3	8.8
	3	9.2	9.5	9.7	9.6	9.1	8.7	9.3	8.6
	4	9.2	9.5			9.1	8.7	9.3	8.5
	5	9.2	9.4			9.2	8.6	9.2	8.4
	6					9.2	8.6	9.2	8.4
	7					9.2	8.6	9.2	8.5
	8							9.2	8.4
	9							9.2	8.3
	10							9.2	8.3
890228	0							0.2	14.4
	1							3.0	14.5
	2							3.0	14.3
	3							2.9	14.2
	4							3.0	13.8
	5				UNDER ICE			3.1	12.5
	6							3.4	9.8
	7							3.5	7.0

Table 1.3. cont'd

Date	(m)	Station 6		Station 7		Station 8		Station 9		Station 10		Station 11	
		Temp	O2	Temp	O2	Temp	O2	Temp	O2	Temp	O2	Temp	O2
860429	0			13.1	12.0			11.5	12.0				
	1			13.1	12.0			11.0	12.1	12.5	12.0		
	2			13.0	11.8			10.0	12.2	13.0	12.2		
	3			10.0	11.8			9.0	12.5	8.0	12.5		
	4							8.9	12.6				
	5							8.9	12.7	7.0	12.5		
860509	0					15.9	11.6	11.8	12.5			13.8	12.5
	1	13.0	12.6	12.8	13.2	15.1	11.2	11.8	12.8	12.0	12.8	13.8	12.5
	2	12.8	12.0	12.8	13.2	14.9	11.0	11.8	12.6	12.0	12.8	13.7	12.7
	3	12.5	12.4	12.7	13.2			11.8	12.6	12.0	12.8	13.7	12.6
	4	12.2	12.1					11.8	12.5	12.0	12.8	13.5	12.4
	5	12.0	11.0					11.8	12.5	12.0	12.7		
	6							11.8	12.4	12.0	12.6		
	7									12.0	12.6		
860528	0	19.5	11.2	20.0	11.3	23.9	11.5	17.8	8.0	19.0		21.0	11.6
	1	19.4	11.3	20.0	11.4	23.7	11.5	17.7	8.2	19.0	11.2	20.8	11.6
	2	17.4	11.2	19.5	11.6	23.7	11.5	17.0		18.8		20.5	11.6
	3	16.0		17.2				16.9		18.2		20.1	
	4	16.0						16.8		18.0		20.0	
	5	15.8						16.1		17.9			
	6							15.9		16.9			
	7							15.6		16.7			
	8							15.6		15.3	10.5		
860618	0	17.0	8.5	17.4	8.0	18.0	8.9	17.0	7.8	17.1	7.4	17.1	7.8
	1	17.0	8.5	17.4	8.1	18.0	9.0	17.0	7.9	17.1	7.5	17.1	8.0
	2	17.0	8.5	17.3	8.1	16.1	8.3	17.0	?	17.1	7.4	17.1	8.0
	3	17.0	8.5	17.2	8.1	16.0	7.1	17.1	7.9	17.1	7.4	17.1	8.0
	4	16.4	8.5					17.1	7.9	17.1	7.5	17.1	8.0
	5	16.4	8.3					17.1	7.9	17.1	7.5		
	6									17.1	7.5		
	7							17.0	7.9	17.1	7.5		
	8							17.0	7.8	17.0	7.5		

Table 1.4. Temperature (^{o}C) and dissolved oxygen (mg.L^{-1}) measured at six stations on Sturgeon Lake during the 1986 ice-free period.

Date	(m)	Station 6		Station 7		Station 8		Station 9		Station 10		Station 11	
		Temp	O2	Temp	O2	Temp	O2	Temp	O2	Temp	O2	Temp	O2
860709	0	21.4	7.0	22.0	7.4	24.9	8.5	21.7	7.4	21.8	7.4	22.1	7.4
	1	21.4	7.0	22.0	7.3	24.9	8.7	21.2	7.3	21.9	7.5	22.1	7.4
	2	21.2	6.9	21.9	7.3	24.8	6.8	21.0	7.3	21.9	7.5	22.1	7.4
	3	20.8	6.7	21.9	7.2	23.4	4.7	21.0	7.3	21.7	7.4	22.0	7.3
	4	19.5	5.7					21.0	7.3	21.4	7.4	21.9	7.2
	5							20.9	7.3	21.6	7.4	21.8	6.7
	6							20.5	6.8	21.3	7.4		
	7							20.2	6.4	20.9	7.1		
	8							19.5	4.9	20.1	5.7		
860723	0	25.0	7.7	23.9	7.1	26.0	8.7	24.5	7.3	24.1	7.4	24.9	7.2
	1	25.0	7.7	23.8	7.0	24.9	7.6	24.0	7.2	24.1	7.6	24.3	7.4
	2	24.9	7.7	23.8	7.0	24.0	6.3	23.0	7.1	23.2	7.6	23.9	7.2
	3	24.8	7.6	23.5	6.4			22.9	7.0	23.1	7.5	23.5	7.1
	4	23.0	6.9	22.2	6.4			22.8	7.0	23.0	7.6	23.4	6.9
	5	22.1	4.9					22.8	6.6	22.8	7.5	23.1	6.7
	6	21.5	4.2					21.1	3.4	22.8	7.5		
	7							21.1	2.9	22.2	6.5		
	8							19.9	2.8	20.0	5.6		
	9									20.0	4.8		
860806	0	23.5	7.6	22.6	8.2	22.9	6.9	23.0	7.9	23.0	7.2	23.2	7.8
	1	23.3	7.6	22.6	8.2	22.8	6.8	23.0	7.8	23.0	7.2	23.2	7.8
	2	23.3	7.6	22.6	8.2	22.5	5.5	23.0	7.7	23.0	7.2	23.2	7.8
	3	23.2	7.4	22.5	8.2	22.2	5.4	23.0	7.7	23.0	7.2	23.2	7.8
	4	23.1	7.6					23.0	7.7	23.0	7.2	23.1	7.5
	5	23.1	7.4					23.0	7.7	23.0	7.2		
	6							23.0	7.7	23.0	7.1		
	7							22.8	7.7	23.0	7.1		
	8							22.8	7.8	23.0	6.8		
	9							22.8	7.7				
	10							22.8					
860820	0	23.1	7.9	23.2	7.5	24.9	6.7	23.2	8.1	22.5	7.6	22.1	7.2
	1	23.0	8.0	23.2	7.6	24.5	6.6	23.2	8.2	22.5	7.7	22.1	7.4
	2	22.9	8.2	22.9	7.6	24.3	6.4	23.1	8.4	22.5	8.0	21.9	7.6
	3	22.9	8.4	22.5	?	24.0	6.4	23.0	8.7	22.5	8.3	21.9	7.7
	4	22.5	8.5					23.0	8.6	22.5	8.0	21.9	8.1
	5	22.0	7.9					22.9	8.1	22.4	7.9		
	6							21.9	7.2	22.0	7.0		
	7							21.5	6.0	21.7	5.2		
	8							19.5	3.7	21.0	3.3		
	9							19.5	3.3	21.0	3.0		
	10							18.9	2.5				

Table 1.4. cont'd

		Station 33		Station 34		Station 35		Station 36	
	(m)	Temp	O2	Temp	O2	Temp	O2	Temp	O2
860819	0	23.2	9.3	23.4	8.3	23.0	8.2	23.0	8.5
	1	23.0	9.3	23.2	8.4	23.0	8.2	23.0	8.6
	2	22.5	8.3	23.0	8.3	23.0	8.1	23.0	8.1
	3	22.3	7.8	22.8	7.9	22.8	7.7	22.7	8.1
	4	22.2	7.3	22.6	7.2	22.5	7.6	22.6	7.1
	5	22.0	7.2			22.5	7.4	22.6	6.9
	6							22.5	6.1
	7							22.0	3.7
860909	0	17.4	10.2	17.7	10.6	17.3	9.7	17.2	10.0
	1	17.3	10.2	17.7	10.6	17.3	9.7	17.2	9.9
	2	17.3	10.3	17.4	10.5	17.3	9.7	17.0	9.9
	3	17.3	10.2	17.0	10.4	17.3	9.7	17.0	9.9
	4	17.3	10.2			17.2	9.8	17.0	9.9
	0	17.0	10.2			17.1	9.8	17.0	9.9
	6					17.0	9.7	17.0	9.9
861021	0	9.8	9.0	10.1	9.0	10.0	9.5	10.0	9.7
	1	9.8	9.1	10.1	9.6	10.0	9.5	10.0	9.7
	2	9.5	9.1	10.1	9.6	10.0	9.5	10.0	9.8
	3	9.5	9.1	10.1	9.6	9.9	9.5	10.0	9.7
	4			10.1	9.6	9.4	9.5	10.0	9.8
	5					9.9	9.6	10.0	9.7
	6					9.9	9.5		

Table 1.4. cont'd

Date	(m)	Station 6		Station 7		Station 8		Station 9		Station 10		Station 11	
		Temp	O2	Temp	O2	Temp	O2	Temp	O2	Temp	O2	Temp	O2
870505	0	10.8	10.0	12.0	10.4	13.0	10.4	11.5	10.0	11.5	9.7	12.8	10.2
	1	10.8	10.0	12.0	10.4	15.5	10.0	11.5	10.0	11.5	9.8	12.5	10.2
	2	10.8	10.0	13.0	10.0	12.0	10.4	11.5	10.0	11.0	9.7	11.8	10.4
	3	10.5	9.8					11.5	10.0	11.0	9.6	11.0	10.4
	4	10.0	9.6					10.5	9.9	11.0	9.6		
	5							10.5	9.9	10.5	9.5		
	6							10.5	9.9	10.5	9.1		
	7							10.5	9.9	10.0	9.0		
	8							10.5	9.6				
	9							10.0	9.2				
	10							10.0	8.9				
870526	0	15.5	10.0	15.5	9.5	16.0	9.0	16.0	8.8	16.0	8.8	16.0	9.1
	1	15.5	10.0	15.5	9.4	16.0	8.5	16.0	8.8	16.0	8.8	16.0	9.1
	2	15.5	10.0	15.5	9.4	16.0	8.6	16.0	8.9	16.0	8.8	16.0	9.2
	3	15.5	10.0	15.5	9.1			16.0	8.9	16.0	8.8	16.0	9.1
	4	15.5	10.0					16.0	8.9	16.0	8.8		
	5							16.0	8.9	16.0	8.8		
	6							16.0	8.9	16.0	8.8		
	7							16.0	8.9	16.0	7.0		
	8							16.0	8.9	16.0	8.9		
	9							16.0	8.9				
	10							16.0	8.9				
870616	0	20.0	7.0	21.0	7.9	24.0	7.9	21.0	8.0	21.0	8.0	22.0	7.9
	1	20.5	7.0	21.0	7.9	23.5	7.9	21.0	8.0	21.0	7.9	22.0	7.9
	2	20.5	6.7	21.0	7.5			21.0	7.9	21.0	7.9	22.0	7.9
	3	20.5	7.0	21.0	7.5			20.5	7.5	21.0	7.9	22.0	7.9
	4	20.0	6.8					20.5	7.5	20.5	7.9	22.0	7.9
	5							20.0	7.1	20.5	7.9		
	6							20.0	6.8	20.0	7.8		
	7							20.0	6.6	19.5	7.0		
	8							20.0	6.6	18.5	5.2		
	9							19.0	6.0				
870707	0	24.0	7.8	23.5	7.8	24.5	7.8	23.0	7.9	23.0	8.0	23.0	7.8
	1	24.0	7.8	23.0	8.4	24.5	7.6	23.0	8.0	23.0	8.0	23.0	7.8
	2	23.5	7.8	22.5	8.0	24.5	6.6	23.0	8.0	23.0	8.0	23.0	7.8
	3	23.5	7.8	22.0	6.8			23.0	8.0	23.0	8.0	23.0	7.8
	4	23.3	7.6					22.9	7.9	22.0	7.8		
	5	22.5	6.8					22.0	7.4	22.0	7.6		
	6							21.5	7.1	22.0	7.4		
	7							21.5	6.4	21.5	6.8		
	8							21.5	6.6				
	9							21.5	5.0				
	10							21.0	4.8				

Table 1.5. Temperature (°C) and dissolved oxygen ($mg.L^{-1}$) measured at six stations on Sturgeon Lake during the 1987 ice-free period.

Date	m)	Station 6		Station 7		Station 8		Station 9		Station 10		Station 11	
		Temp	O2	Temp	O2	Temp	O2	Temp	O2	Temp	O2	Temp	O2
870728	0	24.0	6.9	24.0	7.7	24.5	7.9	24.5	7.2	25.0	7.0	24.5	7.2
	1	24.0	6.9	24.0	7.7	24.5	8.0	24.5	7.2	25.0	7.0	24.5	7.2
	2	24.0	7.3	24.0	7.7	24.0	7.3	24.5	7.1	24.5	7.0	24.0	7.2
	3	24.0	7.3	23.0	7.2			24.3	7.0	24.5	6.9	24.0	7.0
	4							24.3	6.9	24.5	6.9	24.0	7.0
	5							24.3	6.8	24.0	6.8		
	6							24.0	6.8	24.0	6.7		
	7							24.0	6.7	24.0	6.7		
	8							24.0	6.7				
	9							24.0	6.7				
	10							24.0	6.7				
870818	0	23.5	7.4	23.0	7.5	24.0	7.2	23.0	7.6	23.0	7.7	24.0	7.2
	1	24.0	7.5	23.0	7.5	25.0	7.2	23.0	7.6	23.0	7.7	24.0	7.2
	2	24.0	7.5	23.0	7.5	24.0	6.8	23.0	7.6	23.0	7.7	24.0	7.1
	3	24.0	7.5	23.0	7.5			23.0	7.3	23.0	7.7	24.0	7.1
	4	24.0	7.4					23.0	7.1	23.0	7.7		
	5	23.5	6.7					23.0	7.2	23.0	7.6		
	6							23.0	7.2	23.0	7.5		
	7							23.0	7.2	23.0	7.4		
	8							23.0	7.2	23.0	7.5		
	9							23.0	7.2				
	10							23.0	7.2				
870909	0	19.5	7.8	19.0	7.9	20.0	7.7	19.0	8.6	19.5	8.7	20.0	8.4
	1	19.5	7.8	19.0	7.9	20.0	7.7	19.0	8.6	19.5	8.7	20.0	8.4
	2	19.5	7.8	19.0	7.9	20.0	7.3	19.0	8.5	19.5	8.7	20.0	8.3
	3	19.0	7.7	19.0	7.8			19.0	8.4	19.5	8.6	19.0	7.3
	4	19.0	6.9					19.0	7.8	19.0	8.5	19.0	5.7
	5	18.5	6.4					18.5	6.5	19.0	8.5		
	6							18.0	5.5	19.0	8.1		
	7							18.0	5.5	18.5	5.7		
	8							18.0	5.3	18.0	5.5		
	9							18.0	4.7				
	11							18.0	4.5				
870929	0	17.0	9.2	16.0	8.9	17.0	9.8	16.0	9.3	16.0	9.2	16.0	9.5
	1	17.0	9.4	16.0	9.1	16.5	9.9	16.0	9.3	16.0	9.2	16.0	9.5
	2	16.5	9.4	15.5	9.2	17.0	10.0	16.0	9.3	16.0	9.2	16.0	9.6
	3	16.5	9.2	15.5	9.1			16.0	9.2	16.0	9.2	16.0	9.6
	4	16.0	9.3					16.0	9.2	16.0	9.2	16.0	9.5
	5							16.0	9.2	16.0	9.2		
	6							16.0	9.3	15.5	9.1		
	7							16.0	9.3	15.5	9.1		
	8							16.0	9.3	15.5	9.1		
	9							16.0	9.3	15.5	9.1		
	10							16.0	9.3				

Table 1.5: cont'd

Date	m)	Station 6		Station 7		Station 8		Station 9		Station 10		Station 11	
		Temp	O2	Temp	O2	Temp	O2	Temp	O2	Temp	O2	Temp	O2
871021	0	9.5	10.2	9.0	10.2	7.5	10.4	9.5	10.0	10.0	10.1	9.5	10.2
	1	9.8	10.2	9.0	10.2	7.5	10.4	9.5	10.0	10.0	10.1	9.5	10.2
	2	9.8	10.3	9.0	10.2	7.5	10.4	9.5	10.1	10.0	10.1	9.5	10.2
	3	9.6	10.3	9.0	10.2			9.5	10.1	10.0	10.1	9.5	10.2
	4	9.6	10.2					9.5	10.1	10.0	10.1		
	5							9.5	10.1	10.0	10.0		
	6							9.5	10.1	10.0	10.1		
	7							9.5	10.1	10.0	10.1		
	8							9.5	10.1	10.0	10.1		
	10							9.5	10.1				

Table 1.5: cont'd

Date	(m)	Station 6		Station 7		Station 8		Station 9		Station 10		Station 11	
		Temp	O2	Temp	O2	Temp	O2	Temp	O2	Temp	O2	Temp	O2
880502	0	8.9	10.8	11.0	10.6	12.5	10.0	9.0	10.2	8.3	10.3	8.0	10.0
	1	8.9	11.0	11.0	10.6	12.0	10.0	9.0	10.3	8.3	10.3	8.0	10.2
	2	8.5	11.0	11.0	10.6	11.5	10.0	9.0	10.4	8.3	10.3	8.0	10.2
	3	8.0	11.1	10.5	10.7			9.0	10.4	8.2	10.3	8.0	10.2
	4	7.9	11.1					9.0	10.4	8.2	10.3		
	5	7.9	11.1					9.0	10.3	8.2	10.2		
	6							8.5	10.3	7.9	10.0		
	7							8.5	10.3	7.7	9.9		
	8							8.5	10.3	7.5	9.6		
	9							8.0	9.8				
	11							7.5	9.6				
880517	0	12.5	9.9	13.5	9.5	13.5	8.0	13.0	9.4	12.7	8.8	13.5	9.0
	1	12.5	9.8	13.7	9.4	13.9	8.0	13.0	9.4	12.7	8.8	13.5	8.9
	2	12.5	9.8	13.7	9.4	13.8	7.0	13.0	9.3	12.7	8.8	13.5	8.9
	3	12.5	9.8	13.7	9.4			13.0	9.3	12.7	8.8	13.5	8.9
	4	12.5	9.8					13.0	9.3	12.7	8.8	13.5	8.9
	5							13.0	9.3	12.7	8.8		
	6							12.5	9.1	12.7	8.8		
	7							12.5	8.8	12.7	8.8		
	8							12.5	8.5				
	9							12.0	7.9				
	10							12.0	7.6				
880607	0	17.8	7.5	18.2	8.2	18.5	8.2	18.2	7.9	18.2	7.9	18.5	7.8
	1	17.8	7.5	18.2	8.2	18.5	8.0	18.2	7.9	18.2	7.8	18.5	7.8
	2	17.8	7.5	18.3	8.1	17.9	7.7	18.2	7.9	18.2	7.8	18.5	7.8
	3	17.8	7.5	18.2	8.1			18.1	7.7	18.2	7.9	18.5	7.8
	4	17.7	7.4					18.1	7.8	18.2	7.8		
	5							18.0	7.8	18.2	7.8		
	6							17.9	7.7	18.2	7.8		
	7							17.9	7.7	18.2	7.8		
	8							17.9	7.7	18.2	7.7		
	9							17.7	6.1				
	10							17.3	5.5				
880628	0	19.2	7.5	19.3	7.9	19.2	8.3	19.7	7.8	20.2	7.6	19.7	7.6
	1	19.2	7.5	19.7	7.9	19.2	8.3	19.7	7.7	20.2	7.6	19.7	7.6
	2	19.2	7.5	19.7	7.8	19.2	8.3	19.8	7.7	20.2	7.6	19.8	7.6
	3	19.2	7.4	19.7	7.8			19.8	7.7	20.2	7.6	19.8	7.6
	4	19.3	7.4					19.8	7.5	20.2	7.6		
	5							19.7	7.5	20.2	7.6		
	6							19.7	7.5	20.2	7.6		
	7							19.7	7.4	20.2	7.6		
	8							19.6	7.3	20.2	7.6		

Table 1.6. Temperature (^{o}C) and dissolved oxygen (mg.L^{-1}) measured at six stations on Sturgeon Lake during the 1988 ice-free period.

Date	m)	Station 6		Station 7		Station 8		Station 9		Station 10		Station 11	
		Temp	O2	Temp	O2	Temp	O2	Temp	O2	Temp	O2	Temp	O2
880719	0	24.4	7.0	25.2	6.9	26.0	7.5	24.3	7.2	24.3	7.2	25.0	6.9
	1	24.3	7.0	24.3	7.1	25.7	7.4	24.3	7.2	24.3	7.2	25.0	6.9
	2	23.5	7.2	23.9	7.1	25.3	7.2	24.0	7.2	24.2	7.2	24.8	6.9
	3	23.1	6.9	23.8	7.0			23.9	7.2	24.2	7.2	24.7	6.8
	4	22.9	6.4					23.9	7.3	24.2	7.2		
	5							23.9	7.2	24.2	7.1		
	6							23.8	7.2	24.2	7.0		
	7							19.8	0.6	23.7	6.4		
	8							19.0	0.2	22.8	5.9		
	9							18.8	0.2				
	10							18.7	0.1				
880809	0	25.7	7.5	24.7	7.2	25.6	8.2	25.2	7.6	25.5	7.7	25.6	7.5
	1	25.7	7.5	24.7	7.2	25.6	8.2	25.2	7.6	25.5	7.7	25.6	7.5
	2	25.8	7.5	24.7	7.2	25.6	7.9	25.2	7.6	25.4	7.6	25.6	7.5
	3	25.7	7.5	23.6	7.1			25.2	7.6	25.3	7.6	25.6	7.5
	4	25.7	7.5					25.0	7.3	25.3	7.4		
	5							24.9	7.2	25.2	7.3		
	6							24.9	7.1	25.1	7.2		
	7							24.9	7.1	25.1	6.6		
	8							24.8	6.6				
	9							24.7	5.2				
	10							23.7	3.4				
880830	0	20.2	8.3	19.8	8.1	18.8	8.5	20.1	8.1	20.5	7.7	20.1	8.0
	1	20.1	8.4	19.8	8.1	18.8	8.3	20.2	7.8	20.5	7.7	19.9	8.1
	2	20.0	8.3	19.4	8.2	18.6	8.0	20.1	7.7	20.5	7.7	19.8	8.0
	3	19.9	8.3	19.3	8.2			20.0	7.6	20.5	7.7	19.8	8.0
	4	19.9	8.2					20.0	7.5	20.5	7.6		
	5							19.9	7.5	20.5	7.5		
	6							19.9	7.5	20.5	7.5		
	7							20.0	7.5	20.5	7.5		
	8							19.9	7.5				
	9							19.9	7.4				
	10							19.9	7.4				
880927	0	16.2	8.7	16.1	8.2	15.8	8.9	16.2	7.3	15.4	7.3	16.2	8.8
	1	16.2	8.7	16.1	8.2	15.7	8.9	16.2	7.0	16.3	7.3	16.2	8.9
	2	16.2	8.8	16.1		15.6	8.9	16.2	7.0	16.4	7.3	16.2	8.9
	3	16.2	8.8	16.1				16.2	7.0	16.4	7.3	16.2	8.9
	4	16.2	8.8					16.2	7.0	16.4	7.2	16.2	8.9
	5							16.2	7.0	16.4	7.2		
	6							16.2	7.0	16.3	7.1		
	7							16.2	7.0	16.3	7.1		
	8							16.2	7.0	16.2	7.1		
	9							16.2	7.0				

Table 1.6. cont'd

Date	(m)	Station 6		Station 7		Station 8		Station 9		Station 10		Station 11	
		Temp	O2	Temp	O2	Temp	O2	Temp	O2	Temp	O2	Temp	O2
881020	0	9.5	9.9	9.3	10.0	8.5	10.0	9.7	9.6	9.8	9.3	9.8	10.1
	1	9.8	9.9	9.2	10.0	8.5	10.0	9.7	9.5	9.9	9.4	9.8	10.2
	2	9.8	9.9	9.2	10.0	8.5	9.9	9.7	9.5	9.9	9.3	9.9	10.2
	3	9.8	9.8	9.2	10.0			9.8	9.5	9.9	9.3	9.9	10.1
	4	9.8	9.8					9.8	9.5	9.9	9.2		
	5	9.8	9.8					9.8	9.4	9.9	9.3		
	6							9.8	9.4	9.9	9.3		
	7							9.8	9.4	10.0	9.3		
	8							9.8	9.4	10.0	9.3		
	9							9.8	9.4				
	10							9.8	9.4				
890228	0							0.3	12.8				
	1							0	13.6				
	2							1.1	13.1				
	3			UNDER ICE				1.7	9.8				
	4							2.4	7.8				
	5							1.3	9.8				
	6							1.6	8				

Table 1.6. cont'd

Table 1.7: Water quality statistics for Station RE33 in Rice Lake: 1986-1988.

	P $ug.L^{-1}$	NH4 $ug.L^{-1}$	TKN $ug.L^{-1}$	NO2 $ug.L^{-1}$	NO3 $ug.L^{-1}$
Mean	33	71	648	5	47
Std. Deviation	18	63	258	5	120
Minimum	10	2	290	1	5
Maximum	84	332	1310	32	790
First Quartile	19	38	465	3	20
Median	28	50	565	5	20
Third Quartile	43	80	835	6	30
n	40	41	40	41	41

	Na $mg.L^{-1}$	Cl $mg.L^{-1}$	K $mg.L^{-1}$	Cond $uS.cm^{-1}$	Chl a $ug.L^{-1}$
Mean	5.12	8.74	1.10	215	16.4
Std. Deviation	0.38	0.73	0.34	22	19.0
Minimum	4.20	7.25	0.57	167	1.5
Maximum	5.74	10.40	1.83	250	99.0
First Quartile	4.85	8.20	0.74	194	5.7
Median	5.04	8.70	1.20	223	9.8
Third Quartile	5.50	9.20	1.37	232	19.0
n	41	41	41	41	39

Table 1.8: Water quality statistics for Station RE34 in Rice Lake: 1986-1988.

	P $ug.L^{-1}$	NH4 $ug.L^{-1}$	TKN $ug.L^{-1}$	NO2 $ug.L^{-1}$	NO3 $ug.L^{-1}$
Mean	30	69	642	7	232
Std. Deviation	12	39	183	6	1060
Minimum	15	4	370	1	10
Maximum	65	194	1080	30	6590
First Quartile	21	44	520	4	20
Median	26	68	600	6	45
Third Quartile	36	82	730	8	88
n	39	39	39	39	38

	Na $mg.L^{-1}$	Cl $mg.L^{-1}$	K $mg.L^{-1}$	Cond $uS.cm^{-1}$	Chl a $ug.L^{-1}$
Mean	5.18	8.93	1.24	228	15.7
Std. Deviation	0.54	0.91	0.19	13	14.6
Minimum	3.80	6.65	0.94	196	2.6
Maximum	6.40	10.70	1.82	262	59.3
First Quartile	4.81	8.50	1.10	221	6.7
Median	5.36	8.15	1.23	228	9.2
Third Quartile	5.56	9.50	1.34	237	16.3
n	39	39	39	39	38

Table 1.9. Water quality statistics for Station RE35 in Rice Lake: 1986-1988.

	P $ug.L^{-1}$	NH4 $ug.L^{-1}$	TKN $ug.L^{-1}$	NO2 $ug.L^{-1}$	NO3 $ug.L^{-1}$
Mean	29	79	680	5	57
Std. Deviation	12	53	264	5	99
Minimum	11	2	350	2	5
Maximum	57	262	1590	29	610
First Quartile	19	43	505	3	20
Median	26	64	595	5	25
Third Quartile	36	107	800	6	50
n	40	40	40	40	40

	Na $mg.L^{-1}$	Cl $mg.L^{-1}$	K $mg.L^{-1}$	Cond $uS.cm^{-1}$	Chl a $ug.L^{-1}$
Mean	5.12	8.91	1.25	220	16.6
Std. Deviation	0.50	0.95	0.32	12	17.0
Minimum	4.00	6.95	0.78	196	2.5
Maximum	6.22	11.30	2.47	245	86.0
First Quartile	4.69	8.18	1.02	213	5.3
Median	5.29	9.10	1.19	219	9.8
Third Quartile	5.53	9.40	1.40	230	19.8
n	40	40	40	40	38

Table 1.10. Water quality statistics for Station RE36 in Rice Lake: 1986-1988.

	P $ug.L^{-1}$	NH4 $ug.L^{-1}$	TKN $ug.L^{-1}$	NO2 $ug.L^{-1}$	NO3 $ug.L^{-1}$
Mean	25	77	599	5	62
Std. Deviation	9	63	209	4	95
Minimum	5	2	350	1	5
Maximum	46	284	1270	28	540
First Quartile	18	40	470	2	20
Median	22	54	530	4	25
Third Quartile	31	118	680	6	60
n	43	43	43	43	43

	Na $mg.L^{-1}$	Cl $mg.L^{-1}$	K $mg.L^{-1}$	Cond $uS.cm^{-1}$	Chl a $ug.L^{-1}$
Mean	5.07	8.89	1.19	222	14.4
Std. Deviation	0.53	1.02	0.26	17	16.4
Minimum	4.01	6.75	0.72	197	0.1
Maximum	6.60	12.20	1.74	288	86.0
First Quartile	4.60	8.15	0.98	211	4.5
Median	5.20	8.95	1.21	218	7.9
Third Quartile	5.43	9.50	1.39	228	16.3
n	42	43	43	43	41

Table 1.11: Water quality statistics for the Bewdley North inflow of Rice Lake: 1986-1989.

	P $ug.L^{-1}$	NH4 $ug.L^{-1}$	TKN $ug.L^{-1}$	NO2 $ug.L^{-1}$	NO3 $ug.L^{-1}$
Mean	44	39	291	16	837
Std. Deviation	34	50	161	15	363
Minimum	15	2	120	1	210
Maximum	310	634	1730	195	3260
First Quartile	29	16	210	8	598
Median	36	28	250	12	800
Third Quartile	47	44	310	18	983
n	322	330	327	331	330

	Na $mg.L^{-1}$	Cl $mg.L^{-1}$	K $mg.L^{-1}$	Cond $uS.cm^{-1}$
Mean	5.23	5.92	0.94	408
Std. Deviation	2.82	4.27	0.36	43
Minimum	1.32	1.03	0.31	150
Maximum	32.20	46.50	2.20	548
First Quartile	4.08	3.75	0.77	400
Median	4.63	5.30	0.88	412
Third Quartile	5.36	6.40	1.05	425
n	297	329	201	332

Table 1.12: Water quality statistics for the Bewdley South inflow to Rice Lake:1986-1989.

	P $ug.L^{-1}$	NH4 $ug.L^{-1}$	TKN $ug.L^{-1}$	NO2 $ug.L^{-1}$	NO3 $ug.L^{-1}$
Mean	158	172	677	22	1986
Std. Deviation	349	368	1041	29	572
Minimum	12	2	20	1	345
Maximum	3150	2110	7650	405	3830
First Quartile	34	12	190	9	1700
Median	46	22	270	14	1960
Third Quartile	105	89	590	24	2290
n	328	330	329	330	330

	Na $mg.L^{-1}$	Cl $mg.L^{-1}$	K $mg.L^{-1}$	Cond $uS.cm^{-1}$
Mean	4.49	6.60	2.31	444
Std. Deviation	1.10	3.26	1.43	70
Minimum	1.09	2.20	0.38	7
Maximum	12.20	24.20	7.47	585
First Quartile	4.17	4.30	1.43	438
Median	4.34	5.60	1.70	467
Third Quartile	4.85	8.00	2.63	483
n	292	329	194	331

Table 1.13: Water quality statistics for the Indian River inflow to Rice Lake: 1986-1989.

	P $ug.L^{-1}$	NH4 $ug.L^{-1}$	TKN $ug.L^{-1}$	NO2 $ug.L^{-1}$	NO3 $ug.L^{-1}$
Mean	26	57	523	8	166
Std. Deviation	35	87	249	7	194
Minimum	2	2	180	1	5
Maximum	307	706	2600	98	1900
First Quartile	11	18	400	4	30
Median	18	30	460	6	85
Third Quartile	25	58	540	9	245
n	506	513	509	513	513

	Na $mg.L^{-1}$	Cl $mg.L^{-1}$	K $mg.L^{-1}$	Cond $uS.cm^{-1}$
Mean	4.43	8.86	1.34	306
Std. Deviation	1.34	2.67	0.51	58
Minimum	2.67	3.60	0.75	183
Maximum	17.80	30.00	4.65	798
First Quartile	3.76	6.95	1.01	255
Median	4.04	8.29	1.18	313
Third Quartile	4.73	9.80	1.52	347
n	511	512	447	511

Table 1.14. Water quality statistics for the Ouse River inflow to Rice Lake: 1986-1989.

	P $ug.L^{-1}$	NH4 $ug.L^{-1}$	TKN $ug.L^{-1}$	NO2 $ug.L^{-1}$	NO3 $ug.L^{-1}$
Mean	30	59	559	16	499
Std. Deviation	21	79	198	16	256
Minimum	3	2	280	1	30
Maximum	173	692	1880	97	1450
First Quartile	17	19	450	7	293
Median	27	42	520	11	465
Third Quartile	36	66	600	19	638
n	309	310	313	310	310

	Na $mg.L^{-1}$	Cl $mg.L^{-1}$	K $mg.L^{-1}$	Cond $uS.cm^{-1}$
Mean	6.32	13.17	1.40	425
Std. Deviation	3.04	6.14	0.59	65
Minimum	2.24	5.30	0.01	270
Maximum	16.70	34.00	4.43	997
First Quartile	4.11	8.50	1.03	390
Median	5.31	11.20	1.21	410
Third Quartile	7.36	16.30	1.67	457
n	308	306	250	311

Table 1.15: Water quality statistics for the Otonabee River, the major inlet to Rice Lake:1986-1989.

	P $ug.L^{-1}$	NH4 $ug.L^{-1}$	TKN $ug.L^{-1}$	NO2 $ug.L^{-1}$	NO3 $ug.L^{-1}$
Mean	29	101	533	13	185
Std. Deviation	26	63	160	11	128
Minimum	5	2	170	1	5
Maximum	290	490	1800	97	1430
First Quartile	18	60	450	7	110
Median	24	86	500	10	175
Third Quartile	33	124	580	15	220
n	438	444	442	444	444

	Na $mg.L^{-1}$	Cl $mg.L^{-1}$	K $mg.L^{-1}$	Cond $uS.cm^{-1}$
Mean	5.36	9.54	1.20	238
Std. Deviation	1.11	2.21	0.22	24
Minimum	3.64	6.00	0.64	190
Maximum	15.50	26.00	2.66	441
First Quartile	4.71	8.45	1.09	223
Median	5.26	9.10	1.18	237
Third Quartile	5.78	10.20	1.25	248
n	442	444	405	444

Table 1.16. Water quality statistics for the Trent River at Hastings, the outlet for Rice Lake: 1986-1989.

	P $ug.L^{-1}$	NH4 $ug.L^{-1}$	TKN $ug.L^{-1}$	NO2 $ug.L^{-1}$	NO3 $ug.L^{-1}$
Mean	22	72	550	6	122
Std. Deviation	9	45	166	6	111
Minimum	2	2	130	1	5
Maximum	83	292	1280	58	485
First Quartile	16	45	450	4	20
Median	20	62	510	5	85
Third Quartile	26	84	580	7	205
n	368	370	371	371	371

	Na $mg.L^{-1}$	Cl $mg.L^{-1}$	K $mg.L^{-1}$	Cond $uS.cm^{-1}$	Chl a $ug.L^{-1}$
Mean	5.09	9.05	1.19	236	10.9
Std. Deviation	0.65	1.18	0.24	19	11.3
Minimum	3.78	6.50	0.75	207	0.3
Maximum	7.84	13.60	3.49	310	84.0
First Quartile	4.60	8.15	1.04	220	3.4
Median	5.02	9.00	1.17	233	6.8
Third Quartile	5.40	9.60	1.31	250	14.3
n	366	365	322	369	150

Table 1.17: Water quality statistics for Station SN6 on Sturgeon Lake: 1986-1988.

	P $ug.L^{-1}$	NH4 $ug.L^{-1}$	TKN $ug.L^{-1}$	NO2 $ug.L^{-1}$	NO3 $ug.L^{-1}$
Mean	17	44	439	6	76
Std. Deviation	12	29	202	7	169
Minimum	5	6	280	1	10
Maximum	70	156	1130	34	925
First Quartile	12	24	340	3	20
Median	14	43	380	4	43
Third Quartile	19	49	445	6	63
n	28	28	28	28	28

	Na $mg.L^{-1}$	Cl $mg.L^{-1}$	K $mg.L^{-1}$	Cond $uS.cm^{-1}$	Chl a $ug.L^{-1}$
Mean	3.08	5.16	0.90	157	5.4
Std. Deviation	0.36	0.72	0.12	18	3.0
Minimum	2.31	3.75	0.74	125	1.7
Maximum	3.66	6.50	1.40	191	13.2
First Quartile	2.83	4.70	0.83	140	2.9
Median	3.13	5.20	0.89	160	4.7
Third Quartile	3.36	5.70	0.96	167	6.8
n	28	27	28	28	25

Table 1.18. Water quality statistics for Station SN7 on Sturgeon Lake: 1986-1988.

	P $ug.L^{-1}$	NH4 $ug.L^{-1}$	TKN $ug.L^{-1}$	NO2 $ug.L^{-1}$	NO3 $ug.L^{-1}$
Mean	24	36	546	5	52
Std. Deviation	20	17	288	4	51
Minimum	8	6	330	1	5
Maximum	110	82	1880	17	205
First Quartile	16	24	420	3	20
Median	19	34	470	3	25
Third Quartile	24	49	550	6	78
n	28	28	28	28	28

	Na $mg.L^{-1}$	Cl $mg.L^{-1}$	K $mg.L^{-1}$	Cond $uS.cm^{-1}$	Chl a $ug.L^{-1}$
Mean	4.19	7.38	1.07	200	10.7
Std. Deviation	0.84	1.82	0.24	35	6.4
Minimum	3.11	5.15	0.84	156	2.6
Maximum	6.55	12.60	2.07	299	29.0
First Quartile	3.60	6.00	0.91	173	5.1
Median	4.06	6.85	1.05	192	9.9
Third Quartile	4.32	7.80	1.14	213	15.2
n	29	29	29	29	28

Table 1.19. Water quality statistics for Station SN8 on Sturgeon Lake: 1986-1988.

	P $ug.L^{-1}$	NH4 $ug.L^{-1}$	TKN $ug.L^{-1}$	NO2 $ug.L^{-1}$	NO3 $ug.L^{-1}$
Mean	66	124	1083	16	139
Std. Deviation	29	111	259	17	145
Minimum	14	8	350	2	10
Maximum	139	398	1400	88	525
First Quartile	44	30	860	5	20
Median	61	92	1120	12	50
Third Quartile	91	140	1320	17	260
n	29	29	29	29	29

	Na $mg.L^{-1}$	Cl $mg.L^{-1}$	K $mg.L^{-1}$	Cond $uS.cm^{-1}$	Chl a $ug.L^{-1}$
Mean	13.72	23.30	2.25	395	29.9
Std. Deviation	4.43	5.47	0.34	41	41.7
Minimum	7.77	15.00	1.33	321	4.6
Maximum	24.20	35.00	3.11	476	240.0
First Quartile	9.22	18.20	2.08	353	13.0
Median	12.60	22.40	2.22	391	23.4
Third Quartile	16.60	26.80	2.40	434	32.6
n	29	28	29	29	29

Table 1.20. Water quality statistics for Station SN9 on Sturgeon Lake: 1986-1988.

	P $ug.L^{-1}$	NH4 $ug.L^{-1}$	TKN $ug.L^{-1}$	NO2 $ug.L^{-1}$	NO3 $ug.L^{-1}$
Mean	23	57	485	5	61
Std. Deviation	14	35	125	5	81
Minimum	7	8	270	1	5
Maximum	76	172	900	3	425
First Quartile	14	30	400	2	20
Median	19	51	455	4	35
Third Quartile	26	71	520	7	68
n	58	58	58	58	58

	Na $mg.L^{-1}$	Cl $mg.L^{-1}$	K $mg.L^{-1}$	Cond $uS.cm^{-1}$	Chl a $ug.L^{-1}$
Mean	3.98	7.06	1.04	196	7.2
Std. Deviation	1.16	2.83	0.18	47	5.2
Minimum	3.34	5.20	0.83	154	0.5
Maximum	11.40	24.10	1.97	485	20.0
First Quartile	3.61	6.10	0.93	175	3.2
Median	3.76	6.53	1.00	189	5.9
Third Quartile	3.99	7.02	1.10	200	9.2
n	58	58	58	58	30

Table 1.21: Water quality statistics for Station SN10 on Sturgeon Lake: 1986-1988.

	P $ug.L^{-1}$	NH4 $ug.L^{-1}$	TKN $ug.L^{-1}$	NO2 $ug.L^{-1}$	NO3 $ug.L^{-1}$
Mean	18	45	455	5	56
Std. Deviation	11	23	108	4	50
Minimum	5	6	260	1	5
Maximum	59	112	680	15	210
First Quartile	11	30	395	2	20
Median	16	42	430	4	40
Third Quartile	20	58	535	6	70
n	28	29	28	29	29

	Na $mg.L^{-1}$	Cl $mg.L^{-1}$	K $mg.L^{-1}$	Cond $uS.cm^{-1}$	Chl a $ug.L^{-1}$
Mean	3.86	6.65	1.02	190	7.1
Std. Deviation	0.25	0.58	0.11	16	5.3
Minimum	3.40	5.40	0.83	159	0.6
Maximum	4.46	7.70	1.38	221	20.0
First Quartile	3.64	6.20	0.95	174	2.6
Median	3.84	6.60	1.00	193	5.3
Third Quartile	4.02	7.15	1.09	200	11.6
n	29	29	29	29	29

Table 1.22. Water quality statistics for Station SN11 on Sturgeon Lake: 1986-1988.

	P $ug.L^{-1}$	NH4 $ug.L^{-1}$	TKN $ug.L^{-1}$	NO2 $ug.L^{-1}$	NO3 $ug.L^{-1}$
Mean	18	41	472	5	55
Std. Deviation	9	23	109	4	57
Minimum	6	2	300	1	5
Maximum	44	86	740	19	220
First Quartile	13	25	410	2	20
Median	16	36	450	4	33
Third Quartile	20	51	535	6	65
n	28	28	28	28	28

	Na $mg.L^{-1}$	Cl $mg.L^{-1}$	K $mg.L^{-1}$	Cond $uS.cm^{-1}$	Chl a $ug.L^{-1}$
Mean	3.82	6.66	1.01	192	6.2
Std. Deviation	0.22	0.53	0.10	17	3.6
Minimum	3.44	5.40	0.85	164	0.3
Maximum	4.38	7.80	1.32	224	15.0
First Quartile	3.64	6.38	0.95	178	4.0
Median	3.81	6.75	1.01	192	5.7
Third Quartile	3.97	7.02	1.06	204	8.7
n	28	28	28	28	28

Table 1.23: Water quality statistics for the McLaren Creek inflow to Sturgeon Lake:1986-1989.

	P $ug.L^{-1}$	NH4 $ug.L^{-1}$	TKN $ug.L^{-1}$	NO2 $ug.L^{-1}$	NO3 $ug.L^{-1}$
Mean	25	51	700	16	979
Std. Deviation	19	55	230	16	707
Minimum	2	2	150	1	15
Maximum	126	354	2100	113	28
First Quartile	16	18	550	7	408
Median	19	32	670	11	845
Third Quartile	30	60	800	17	1470
n	278	281	281	281	280

	Na $mg.L^{-1}$	Cl $mg.L^{-1}$	K $mg.L^{-1}$	Cond $uS.cm^{-1}$
Mean	6.66	16.85	2.00	435
Std. Deviation	2.77	7.90	0.70	90
Minimum	2.24	5.14	0.90	207
Maximum	17.30	45.90	5.36	740
First Quartile	4.86	11.50	1.52	373
Median	5.80	14.05	1.85	414
Third Quartile	7.59	19.93	2.29	481
n	282	282	229	282

Table 1.24: Water quality statistics for the Rutherford Creek inflow to Sturgeon Lake:1986-1989.

	P $ug.L^{-1}$	NH4 $ug.L^{-1}$	TKN $ug.L^{-1}$	NO2 $ug.L^{-1}$	NO3 $ug.L^{-1}$
Mean	23	33	722	14	1571
Std. Deviation	22	52	207	14	1280
Minimum	3	2	130	1	65
Maximum	230	574	1600	176	8630
First Quartile	12	8	570	6	650
Median	18	18	710	10	1190
Third Quartile	26	34	870	17	2110
n	301	305	305	305	305

	Na $mg.L^{-1}$	Cl $mg.L^{-1}$	K $mg.L^{-1}$	Cond $uS.cm^{-1}$
Mean	5.18	11.92	1.55	459
Std. Deviation	2.78	7.50	0.63	105
Minimum	1.37	3.44	0.50	223
Maximum	15.80	39.30	7.39	758
First Quartile	3.07	6.25	1.25	370
Median	4.27	8.82	1.42	456
Third Quartile	6.82	16.00	1.67	537
n	304	305	246	305

Table 1.25: Water quality statistics for the Hawkers Creek inflow to Sturgeon Lake: 1986-1989.

	P $ug.L^{-1}$	NH4 $ug.L^{-1}$	TKN $ug.L^{-1}$	NO2 $ug.L^{-1}$	NO3 $ug.L^{-1}$
Mean	20	60	517	8	161
Std. Deviation	14	81	167	7	137
Minimum	1	2	210	1	5
Maximum	95	374	1070	62	655
First Quartile	11	10	390	4	55
Median	15	26	490	7	115
Third Quartile	25	58	640	10	240
n	382	389	389	389	389

	Na $mg.L^{-1}$	Cl $mg.L^{-1}$	K $mg.L^{-1}$	Cond $uS.cm^{-1}$
Mean	2.09	4.38	1.07	362
Std. Deviation	0.85	2.04	0.34	67
Minimum	0.74	1.00	0.35	130
Maximum	5.64	12.00	2.34	540
First Quartile	1.52	3.00	0.87	312
Median	1.85	3.77	1.02	360
Third Quartile	2.41	4.90	1.21	405
n	390	390	320	390

Table 1.26: Water quality statistics for the Martin Creek inflow to Sturgeon Lake: 1986-1989.

	P $ug.L^{-1}$	NH4 $ug.L^{-1}$	TKN $ug.L^{-1}$	NO2 $ug.L^{-1}$	NO3 $ug.L^{-1}$
Mean	27	29	419	9	263
Std. Deviation	26	44	206	9	217
Minimum	1	2	140	1	5
Maximum	258	430	2000	64	1200
First Quartile	13	8	310	4	85
Median	18	18	370	6	185
Third Quartile	32	34	450	10	420
n	361	367	368	367	367

	Na $mg.L^{-1}$	Cl $mg.L^{-1}$	K $mg.L^{-1}$	Cond $uS.cm^{-1}$
Mean	3.57	7.76	0.94	389
Std. Deviation	0.85	2.73	0.33	54
Minimum	1.42	3.63	0.24	195
Maximum	8.53	23.00	2.88	530
First Quartile	2.95	6.00	0.75	348
Median	3.56	7.10	0.86	390
Third Quartile	4.17	9.00	1.02	432
n	370	369	302	369

Table 1.27: Water quality statistics for the Dunsford Creek inflow to Sturgeon Lake: 1986-1989.

	P $ug.L^{-1}$	NH4 $ug.L^{-1}$	TKN $ug.L^{-1}$	NO2 $ug.L^{-1}$	NO3 $ug.L^{-1}$
Mean	22	99	853	11	199
Std. Deviation	15	144	301	14	255
Minimum	3	2	250	2	5
Maximum	114	1030	1890	165	1500
First Quartile	14	14	660	5	35
Median	19	38	780	7	105
Third Quartile	25	130	990	11	260
n	445	450	451	450	450

	Na $mg.L^{-1}$	Cl $mg.L^{-1}$	K $mg.L^{-1}$	Cond $uS.cm^{-1}$
Mean	11.14	27.03	1.81	479
Std. Deviation	7.83	17.50	0.64	153
Minimum	3.41	9.54	0.49	1
Maximum	55.11	110.00	4.39	1110
First Quartile	6.84	16.00	1.40	380
Median	8.84	21.20	1.68	451
Third Quartile	11.50	30.00	2.06	547
n	449	445	451	451

Table 1.28. Water quality statistics for the mouth of Emily Creek at Sturgeon Lake:1986-1989.

	P $ug.L^{-1}$	NH4 $ug.L^{-1}$	TKN $ug.L^{-1}$	NO2 $ug.L^{-1}$	NO3 $ug.L^{-1}$
Mean	24	176	873	12	141
Std. Deviation	20	226	517	14	189
Minimum	4	2	160	1	5
Maximum	340	1330	8100	101	1500
First Quartile	16	42	660	4	20
Median	21	64	780	7	40
Third Quartile	27	172	920	13	215
n	606	612	611	612	612

	Na $mg.L^{-1}$	Cl $mg.L^{-1}$	K $mg.L^{-1}$	Cond $uS.cm^{-1}$
Mean	5.54	14.23	1.64	361
Std. Deviation	2.60	7.23	0.70	97
Minimum	2.52	6.50	0.11	1
Maximum	39.30	92.00	4.29	850
First Quartile	4.44	10.60	1.35	294
Median	5.22	12.80	1.63	341
Third Quartile	6.04	15.60	2.03	390
n	612	613	532	615

Table 1.29. Water quality statistics for the inflow to Sturgeon Lake at Fenelon Falls: 1986-1989.

	P $ug.L^{-1}$	NH4 $ug.L^{-1}$	TKN $ug.L^{-1}$	NO2 $ug.L^{-1}$	NO3 $ug.L^{-1}$
Mean	8	37	304	4	83
Std. Deviation	4	20	53	4	62
Minimum	2	6	80	1	5
Maximum	23	108	520	33	230
First Quartile	6	22	280	2	20
Median	8	32	310	3	65
Third Quartile	10	48	440	6	140
n	158	161	159	161	161

	Na $mg.L^{-1}$	Cl $mg.L^{-1}$	K $mg.L^{-1}$	Cond $uS.cm^{-1}$
Mean	2.53	4.15	0.82	132
Std. Deviation	0.19	0.51	0.13	26
Minimum	1.87	2.80	0.64	107
Maximum	3.07	6.40	2.06	420
First Quartile	2.38	3.90	0.77	125
Median	2.54	4.10	0.80	129
Third Quartile	2.66	4.40	0.85	134
n	160	161	137	162

Table 1.30. Water quality statistics for the Scugog River at Lindsay: 1986-1989.

	P $ug.L^{-1}$	NH4 $ug.L^{-1}$	TKN $ug.L^{-1}$	NO2 $ug.L^{-1}$	NO3 $ug.L^{-1}$
Mean	41	109	898	13	483
Std. Deviation	29	100	245	19	464
Minimum	5	2	180	1	5
Maximum	225	930	2230	335	1940
First Quartile	24	43	740	7	73
Median	33	77	875	10	360
Third Quartile	50	141	1020	15	708
n	468	472	473	472	470

	Na $mg.L^{-1}$	Cl $mg.L^{-1}$	K $mg.L^{-1}$	Cond $uS.cm^{-1}$
Mean	9.09	18.74	2.10	396
Std. Deviation	2.43	4.46	0.35	53
Minimum	4.29	9.20	0.95	56
Maximum	31.80	57.90	4.64	557
First Quartile	7.83	16.45	1.92	360
Median	8.75	18.00	2.06	399
Third Quartile	10.10	20.30	2.27	429
n	468	470	393	472

Table 1.31. Water quality statistics for the outlet of Sturgeon Lake to Big Bob Channel in Bobcaygeon: 1986-1989.

	P $ug.L^{-1}$	NH4 $ug.L^{-1}$	TKN $ug.L^{-1}$	NO2 $ug.L^{-1}$	NO3 $ug.L^{-1}$
Mean	15	63	423	8	192
Std. Deviation	9	47	103	8	152
Minimum	2	2	110	1	5
Maximum	68	284	880	54	665
First Quartile	9	36	360	3	40
Median	13	50	410	5	165
Third Quartile	17	78	470	10	300
n	260	261	260	261	261

	Na $mg.L^{-1}$	Cl $mg.L^{-1}$	K $mg.L^{-1}$	Cond $uS.cm^{-1}$	Chl a $ug.L^{-1}$
Mean	4.18	7.68	1.11	206	3.7
Std. Deviation	0.73	1.64	0.19	32	4.3
Minimum	2.82	4.80	0.61	149	0.1
Maximum	7.12	14.50	2.13	322	25.0
First Quartile	3.68	6.50	0.99	182	1.0
Median	3.96	7.10	1.06	200	1.9
Third Quartile	4.50	8.50	1.19	219	4.7
n	253	253	197	260	162

APPENDIX 2.0

Figure 2.1. Frequency histograms of total phosphorus concentrations measured at Rice Lake monitoring sites: 1986-1989.
A.Inflow sites. B.In-lake sites. A-36

Figure 2.2. Frequency histograms of chloride concentrations measured at Rice Lake monitoring sites: 1986-1989.
A.Inflow sites. B.In-lake sites. A-37

Figure 2.3. Frequency histograms of potassium concentrations measured at Rice Lake monitoring sites: 1986-1989.
A.Inflow sites. B.In-lake sites. A-38

Figure 2.4. Frequency histograms of sodium concentrations measured at Rice Lake monitoring sites: 1986-1989.
A.Inflow sites. B.In-lake sites. A-39

Figure 2.5. Frequency histograms of ammonia nitrogen concentrations measured at Rice Lake monitoring sites: 1986-1989.
A.Inflow sites. B.In-lake sites. A-40

Figure 2.6. Frequency histograms of nitrite nitrogen concentrations measured at Rice Lake monitoring sites: 1986-1989.
A.Inflow sites. B.In-lake sites. A-41

Figure 2.7. Frequency histograms of nitrate nitrogen concentrations measured at Rice Lake monitoring sites: 1986-1989.
A.Inflow sites. B.In-lake sites. A-42

Figure 2.8. Frequency histograms of Kjeldahl nitrogen concentrations measured at Rice Lake monitoring sites: 1986-1989.
A.Inflow sites. B.In-lake sites. A-43

Figure 2.9. Frequency histograms of chlorophyll *a* concentrations measured at Rice Lake monitoring sites: 1986-1989. ..... A-44

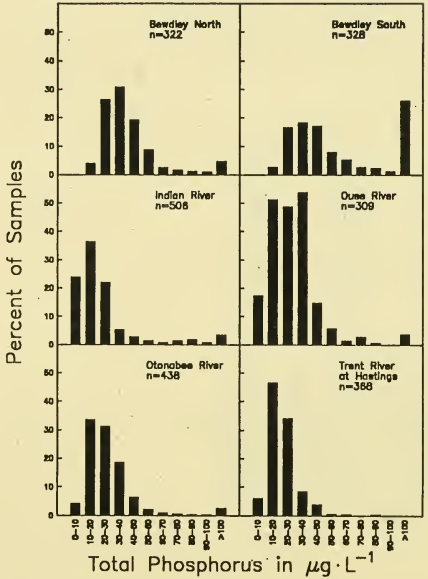

Fig. 2.1A. Frequency histograms of total phosphorus concentrations measured at Rice Lake monitoring sites: 1986-1989.

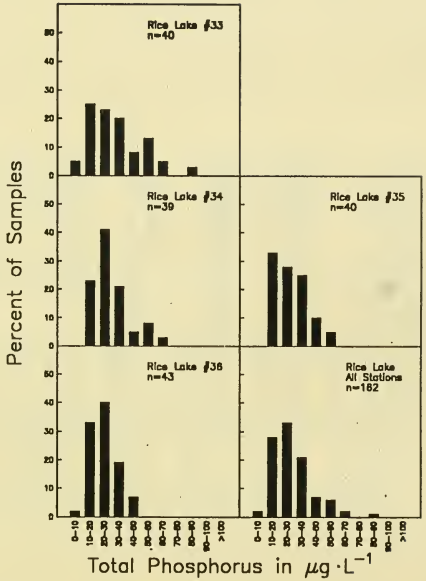

Fig. 2.1B. Frequency histograms of total phosphorus concentrations measured at Rice Lake in-lake sites: 1986-1989.

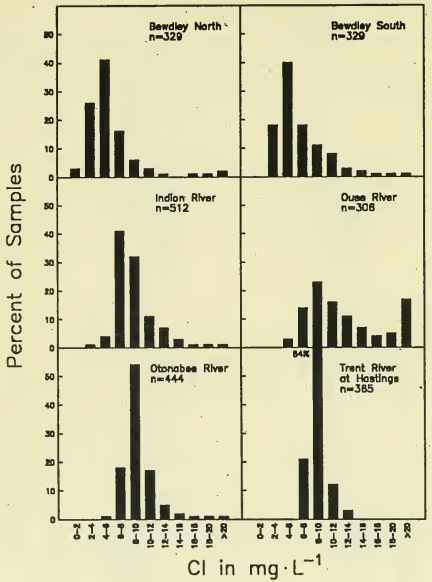

Fig. 2.2A. Frequency histograms of chloride concentrations measured at Rice Lake inflow sites: 1986-1989.

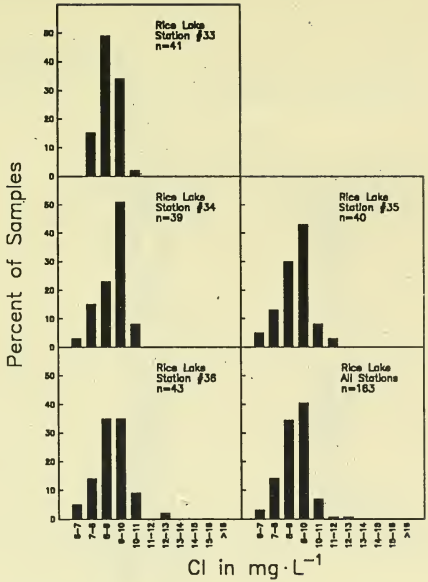

Fig. 2.2B. Frequency histograms of chloride concentrations measured at Rice Lake in-lake sites: 1986-1989.

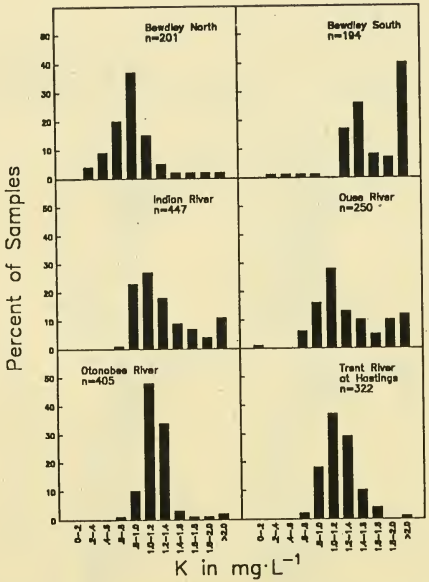

Fig. 2.3A. Frequency histograms of potassium concentrations measured at Rice Lake inflow sites: 1986-1989.

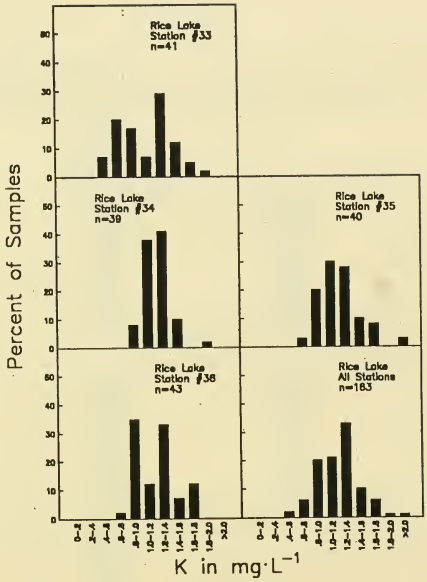

Fig. 2.3B. Frequency histograms of potassium concentrations measured at Rice Lake in-lake sites: 1986-1989.

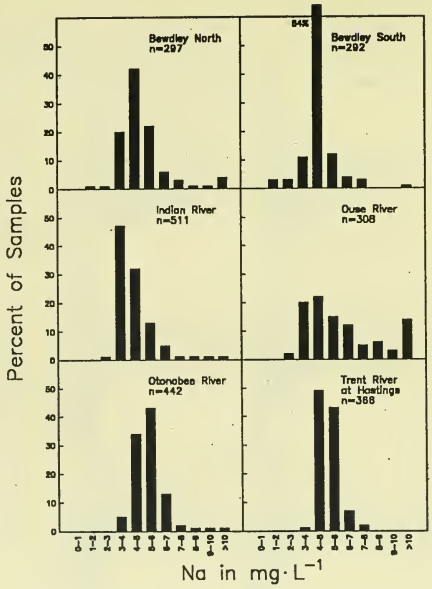

Fig. 2.4A. Frequency histograms of sodium concentrations measured at Rice Lake inflow sites: 1986-1989.

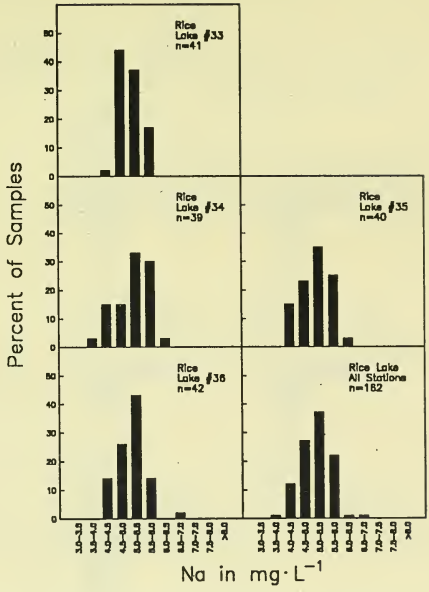

Fig. 2.4B. Frequency histograms of sodium concentrations measured at Rice Lake in-lake sites: 1986-1989.

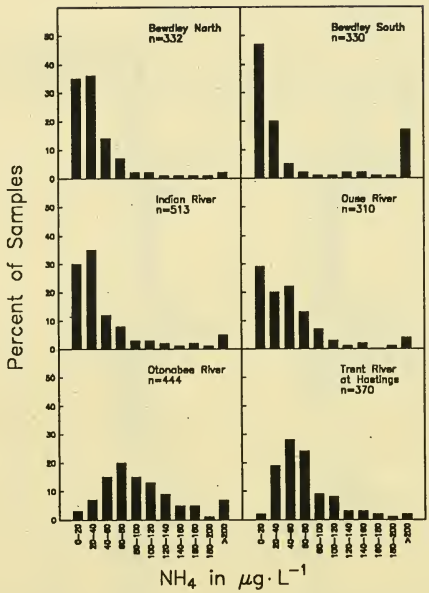

Fig. 2.5A. Frequency histograms of ammonia nitrogen concentrations measured at Rice Lake inflow sites: 1986-1989.

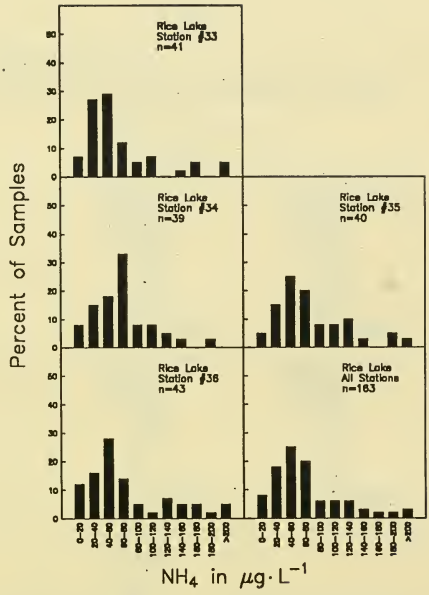

Fig. 2.5B. Frequency histograms of ammonia nitrogen concentrations measured at Rice Lake in-lake sites: 1986-1989.

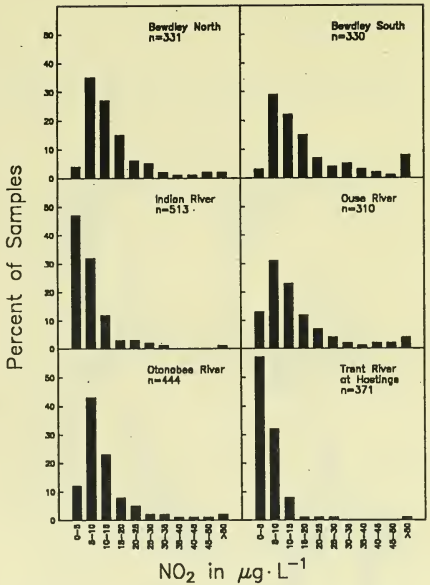

Fig. 2.6A. Frequency histograms of nitrite nitrogen concentrations measured at Rice Lake inflow sites: 1986-1989.

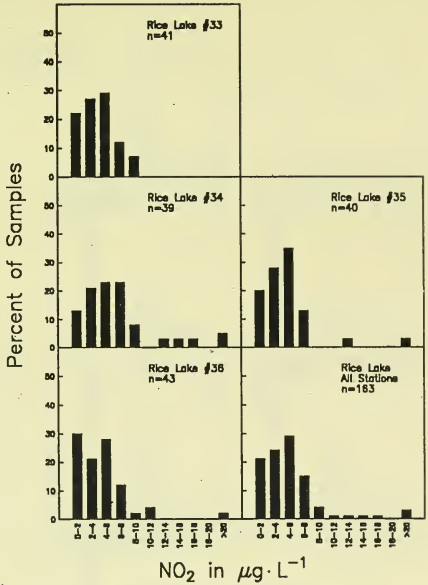

Fig. 2.6B. Frequency histograms of nitrite nitrogen concentrations measured at Rice Lake in-lake sites: 1986-1989.

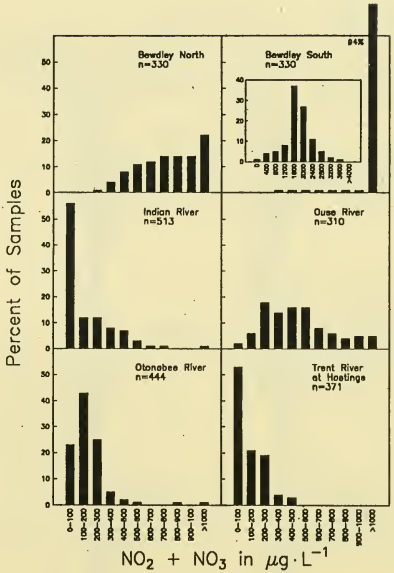

Fig. 2.7A. Frequency histograms for nitrate nitrogen measured at Rice Lake inflow sites: 1986-1989.

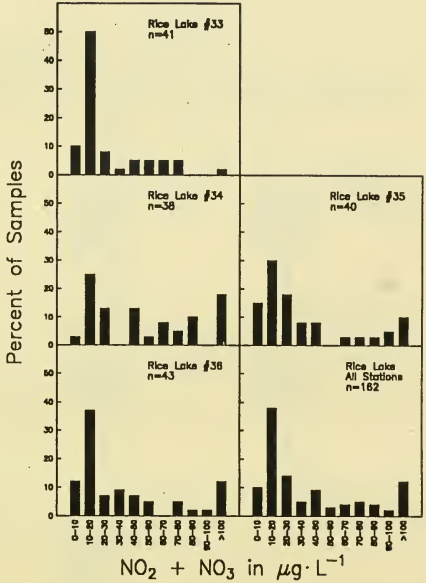

Fig. 2.7B. Frequency histograms of nitrate nitrogen concentrations measured at Rice Lake in-lake sites: 1986-1989.

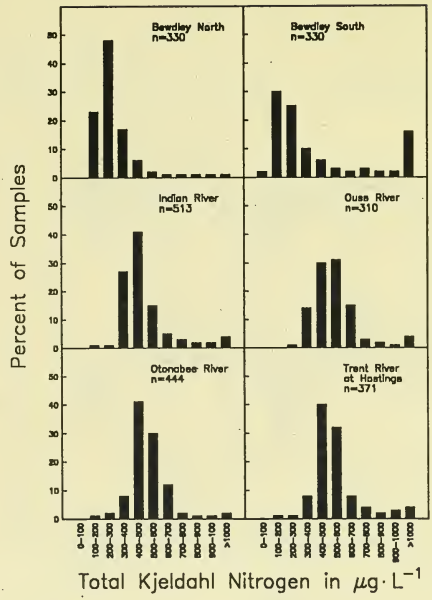

Fig. 2.8A. Frequency histograms of Kjeldahl nitrogen concentrations measured at Rice Lake inflow sites: 1986-1989.

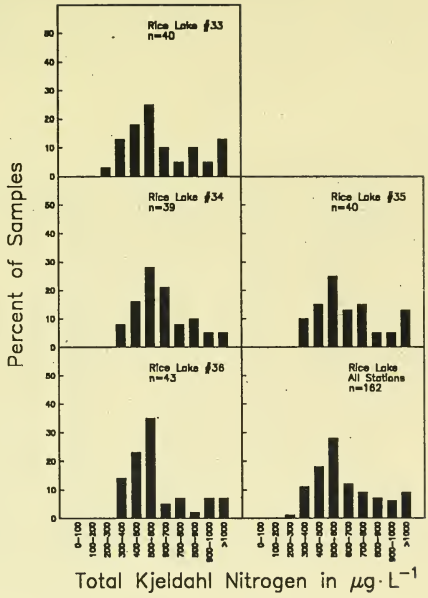

Fig. 2.8B. Frequency histograms of Kjeldahl nitrogen concentrations measured at Rice Lake in-lake sites: 1986-1989.

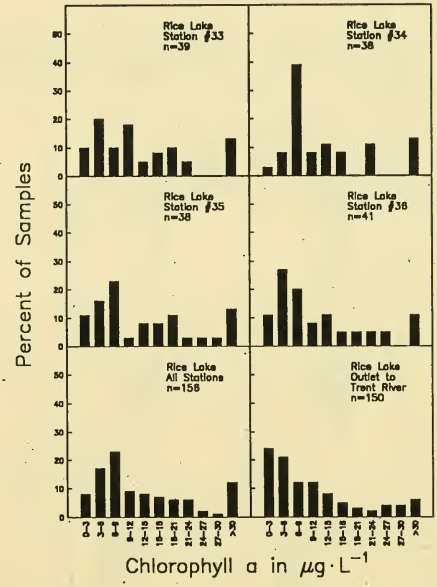

Fig. 2.9. Frequency histograms of chlorophyll a concentrations measured at Rice Lake monitoring sites: 1986-1989.

APPENDIX 3.0

Figure 3.1. Frequency histograms of total phosphorus concentrations measured at Sturgeon Lake monitoring sites: 1986-1989.
A.Inflow sites. B.Major Inflows. C.In-lake sites. A46-A47

Figure 3.2. Frequency histograms of chloride concentrations measured at Sturgeon Lake monitoring sites: 1986-1989.
A.Inflow sites. B.Major Inflows. C.In-lake sites. A47-A48

Figure 3.3. Frequency histograms of sodium concentrations measured at Sturgeon Lake monitoring sites: 1986-1989.
A.Inflow sites. B.Major Inflows. C.In-lake sites. A49-A50

Figure 3.4. Frequency histograms of potassium concentrations measured at Sturgeon Lake monitoring sites: 1986-1989.
A.Inflow sites. B.Major Inflows. C.In-lake sites. A50-A51

Figure 3.5. Frequency histograms of ammonia nitrogen concentrations measured at Sturgeon Lake monitoring sites: 1986-1989.
A.Inflow sites. B.Major Inflows. C.In-lake sites. A52-A53

Figure 3.6. Frequency histograms of nitrite nitrogen concentrations measured at Sturgeon Lake monitoring sites: 1986-1989.
A.Inflow sites. B.Major Inflows. C.In-lake sites. A53-A54

Figure 3.7. Frequency histograms of nitrate nitrogen concentrations measured at Sturgeon Lake monitoring sites: 1986-1989.
A.Inflow sites. B.Major Inflows. C.In-lake sites. A55-A56

Figure 3.8. Frequency histograms of Kjeldahl nitrogen concentrations measured at Sturgeon Lake monitoring sites: 1986-1989.
A.Inflow sites. B.Major Inflows. C.In-lake sites. A56-A57

Figure 3.9. Frequency histograms of chlorophyll a concentrations measured at Sturgeon Lake monitoring sites: 1986-1989.
A.In-lake sites. B.Outflow and mean in-lake. A58

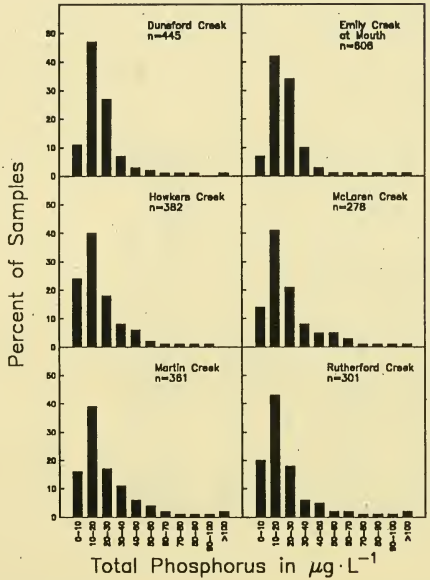

Fig. 3.1A. Frequency histograms of total phosphorus concentrations measured at Sturgeon Lake inflow sites: 1986-1989.

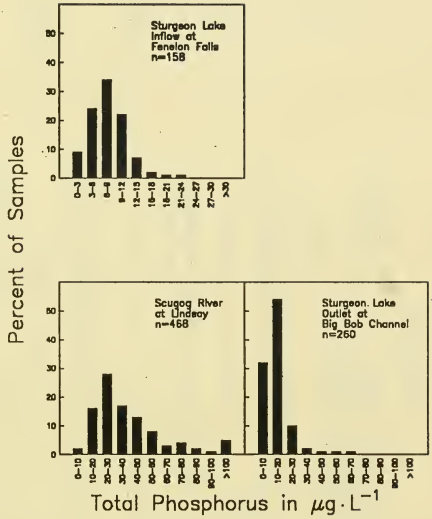

Fig. 3.1B. Frequency histograms of total phosphorus concentrations measured at Sturgeon Lake major inflow sites: 1986-1989.

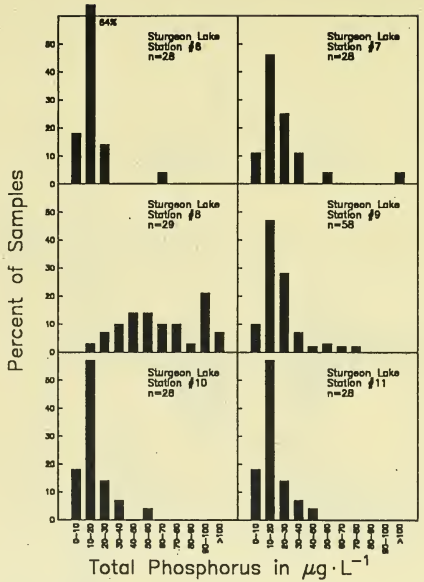
64%
Sturgeon Lake Station #6 n=28
Sturgeon Lake Station #7 n=28
Sturgeon Lake Station #8 n=29
Sturgeon Lake Station #9 n=58
Sturgeon Lake Station #10 n=28
Sturgeon Lake Station #11 n=28
Percent of Samples
Total Phosphorus in $\mu g \cdot L^{-1}$

Fig. 3.1C. Frequency histograms of total phosphorus concentrations measured at Sturgeon Lake in-lake sites: 1986-1989.

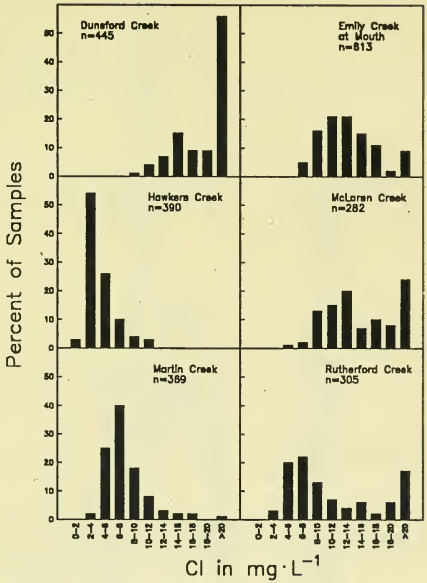

Fig. 3.2A. Frequency histograms of chloride concentrations measured at Sturgeon Lake inflow sites: 1986-1989.

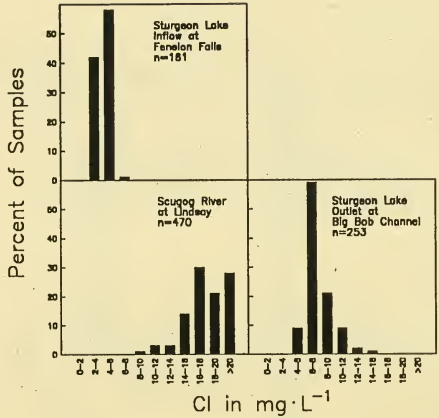

Fig. 3.2B. Frequency histograms of chloride concentrations measured at Sturgeon Lake major inflow sites: 1986-1989.

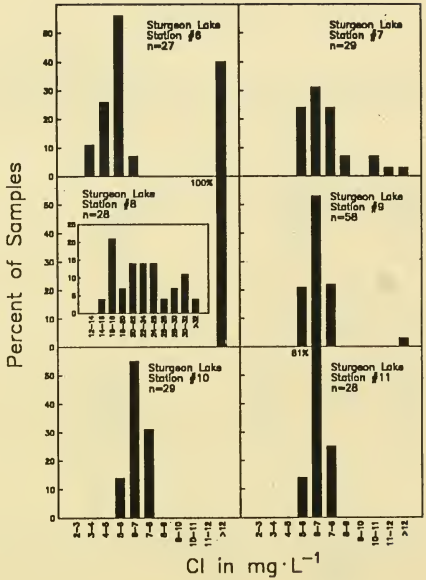

Fig. 3.2C. Frequency histograms of chloride concentrations measured at Sturgeon Lake in-lake sites: 1986-1989.

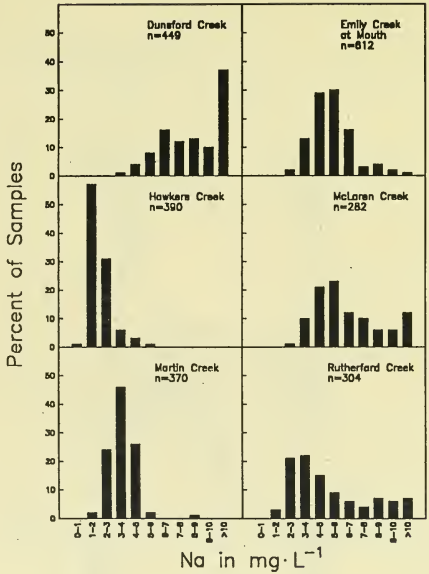

Fig. 3.3A. Frequency histograms of sodium concentrations measured at Sturgeon Lake inflow sites: 1986-1989.

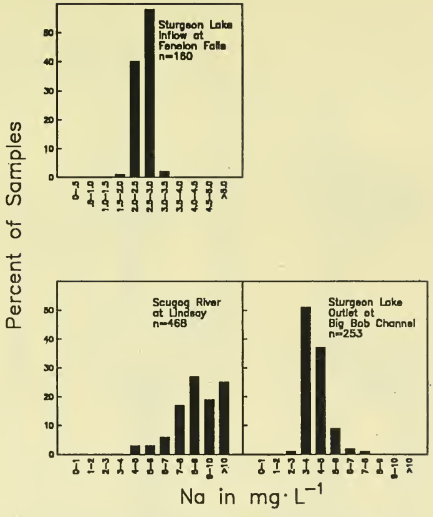

Fig. 3.3B. Frequency histograms of sodium concentrations measured at Sturgeon Lake major inflow sites: 1986-1989.

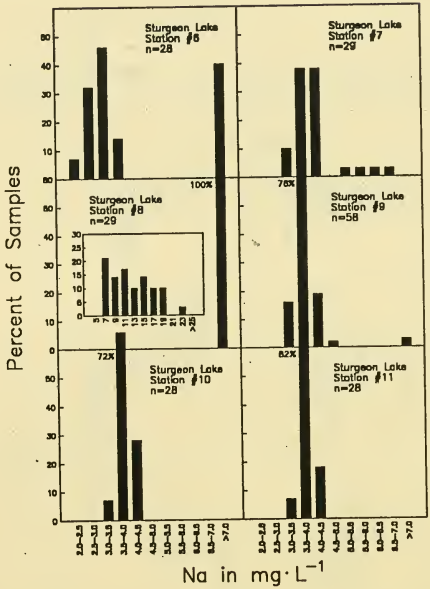

Fig. 3.3C. Frequency histograms of sodium concentrations measured at Sturgeon Lake in-lake sites: 1986-1989.

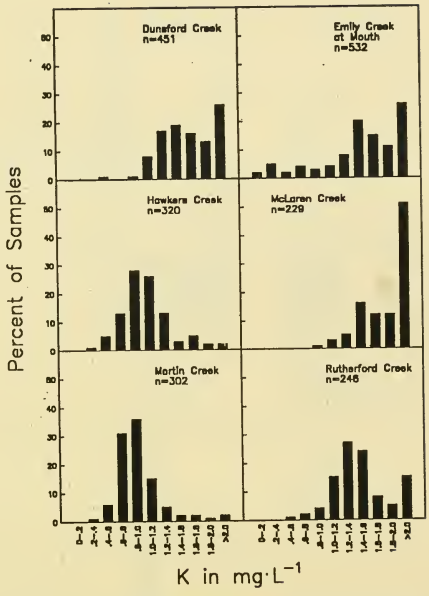

Fig. 3.4A. Frequency histograms of potassium concentrations measured at Sturgeon Lake inflow sites: 1986-1989.

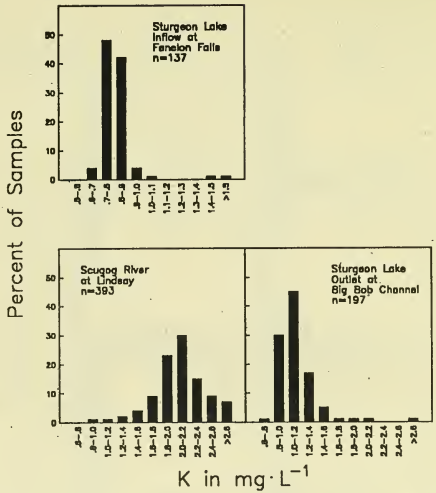

Fig. 3.4B. Frequency histograms of potassium concentrations measured at Sturgeon Lake major inflow sites: 1986-1989.

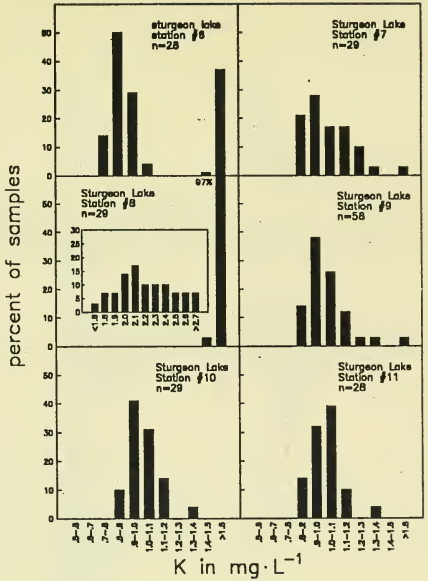

Fig. 3.4C. Frequency histograms of potassium concentrations measured at Sturgeon Lake in-lake sites: 1986-1989.

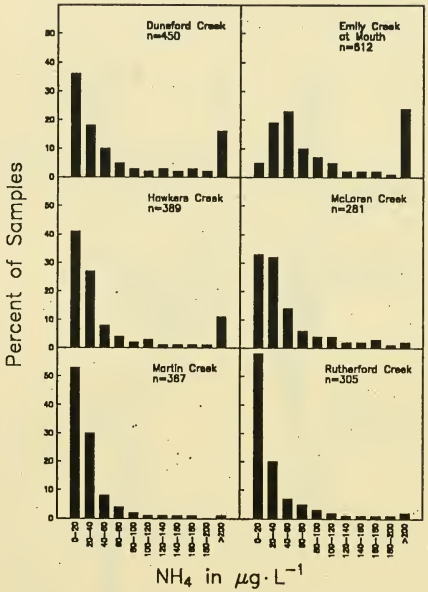

Fig. 3.5A. Frequency histograms of ammonia concentrations measured at Sturgeon Lake inflow sites:1986-1989.

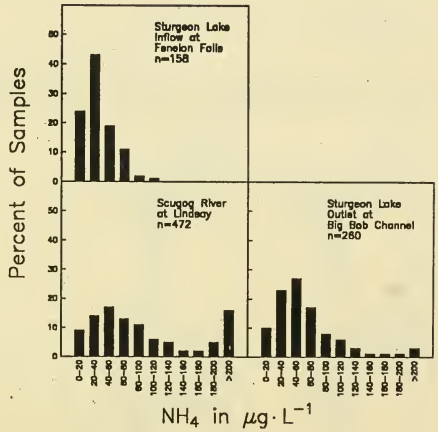

Fig. 3.5B. Frequency histograms of ammonia nitrogen concentrations measured at Sturgeon Lake major inflow sites: 1986-1989.

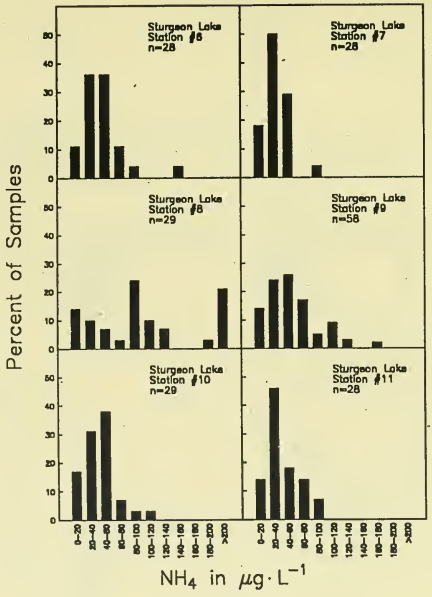
Sturgeon Lake Station #6 n=28
Sturgeon Lake Station #7 n=28
Sturgeon Lake Station #8 n=29
Sturgeon Lake Station #9 n=58
Sturgeon Lake Station #10 n=29
Sturgeon Lake Station #11 n=28
Percent of Samples
NH4 in μg·L−1

Fig. 3.5C. Frequency histograms of ammonia concentrations measured at Sturgeon Lake in-lake sites: 1986-1989.

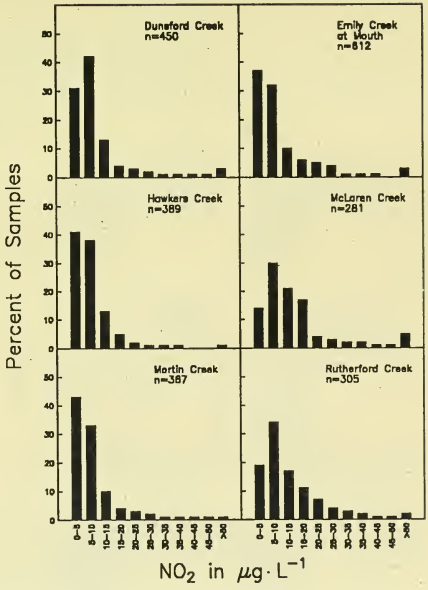

Fig. 3.6A. Frequency histograms of nitrite concentrations measured at Sturgeon Lake inflow sites: 1986-1989.

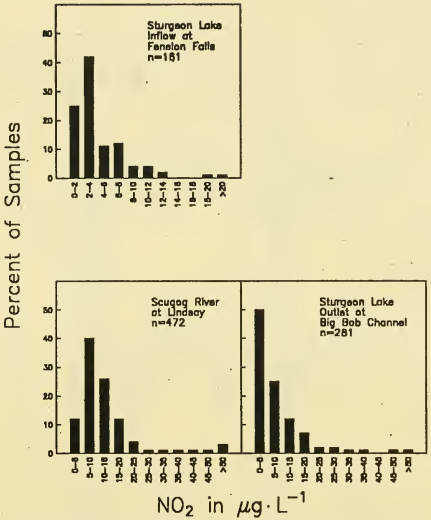

Fig. 3.6B. Frequency histograms of nitrite nitrogen concentrations measured at Sturgeon Lake major inflow sites: 1986-1989.

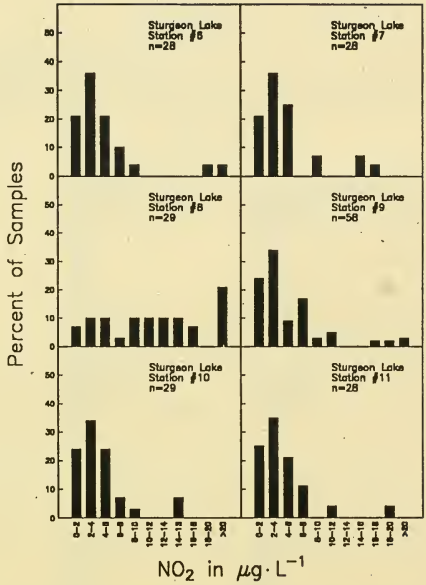

Fig. 3.6C. Frequency histograms of nitrite concentrations measured at Sturgeon Lake in-lake sites: 1986-1989.

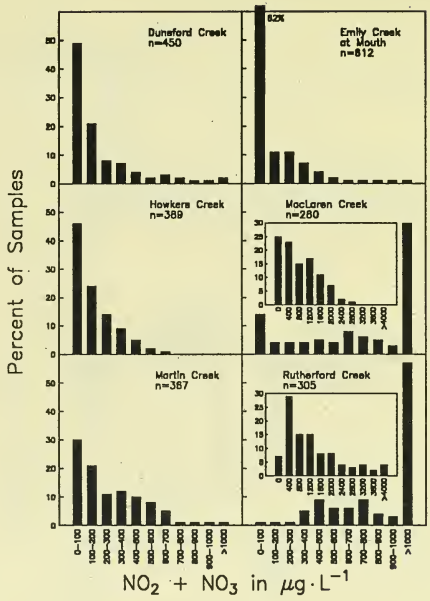

Fig. 3.7A. Frequency histograms of nitrate concentrations measured at Sturgeon Lake inflow sites: 1986-1989.

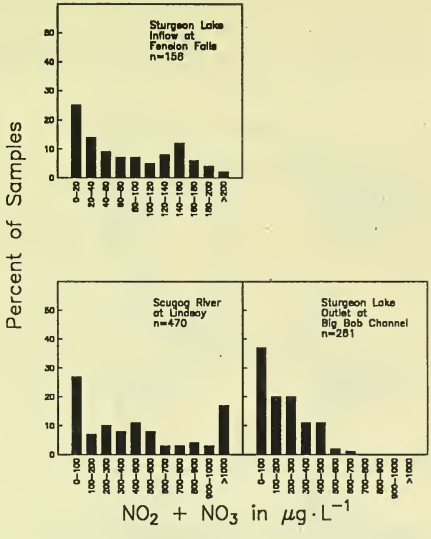

Fig. 3.7B. Frequency histograms of nitrate nitrogen concentrations measured at Sturgeon Lake major inflow sites: 1986-1989.

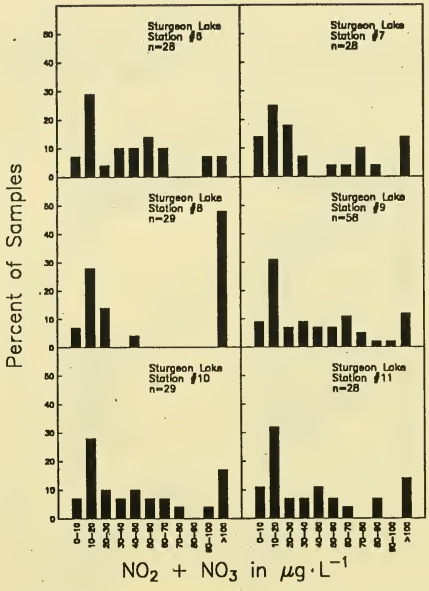

Fig. 3.7C. Frequency histograms of nitrate concentrations measured at Sturgeon Lake in-lake sites: 1986-1989.

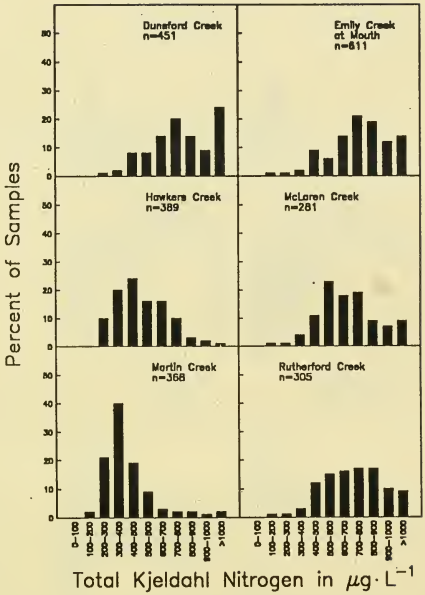

Fig. 3.8A. Frequency histograms of Kjeldahl nitrogen measured at Sturgeon Lake inflow sites: 1986-1989.

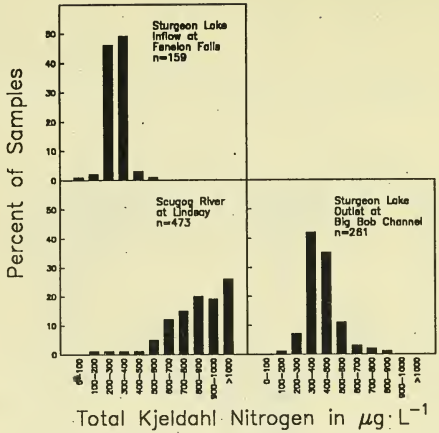

Fig. 3.8B. Frequency histograms of Kjeldahl nitrogen concentrations measured at Sturgeon Lake major inflow sites: 1986-1989.

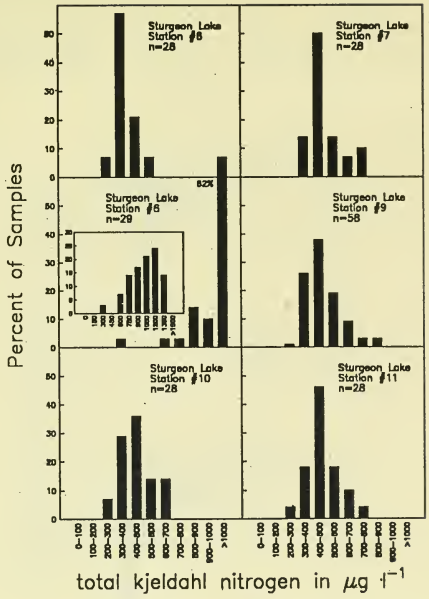

Fig. 3.8. Frequency histograms of Kjeldahl nitrogen measured at Sturgeon Lake in-lake sites: 1986-1989.

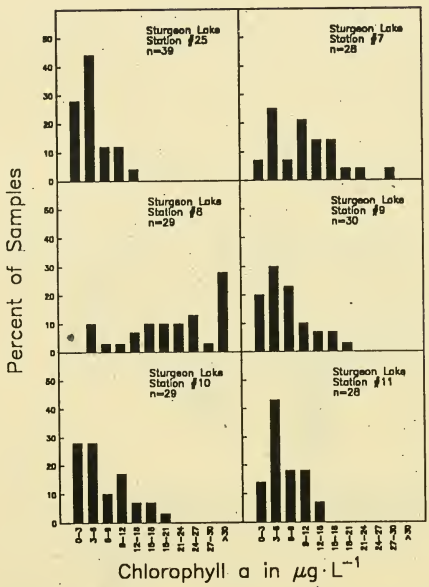

Fig. 3.9A. Frequency histograms of chlorophyll a concentrations measured at Sturgeon Lake in-lake sites: 1986-1989.

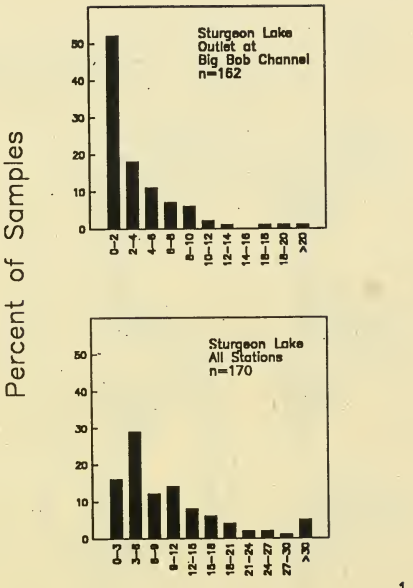

Fig. 3.9B. Frequency histograms of chl a measured in Sturgeon Lake: 1986-1989.

APPENDIX 4.0

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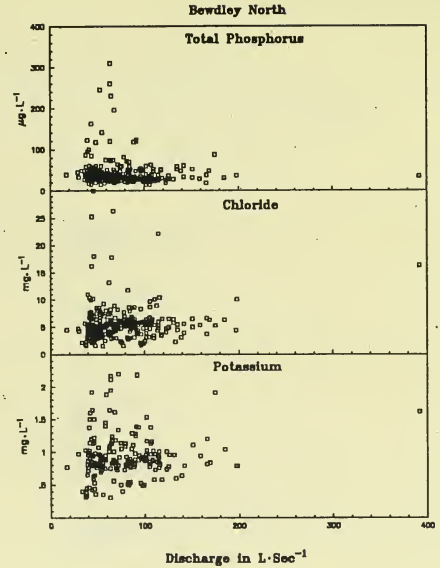

Fig. 4.1.Relationship of total phosphorus, chloride and potassium concentrations to instantaneous discharge at Bewdley North inflow monitoring site: 1986-1989.

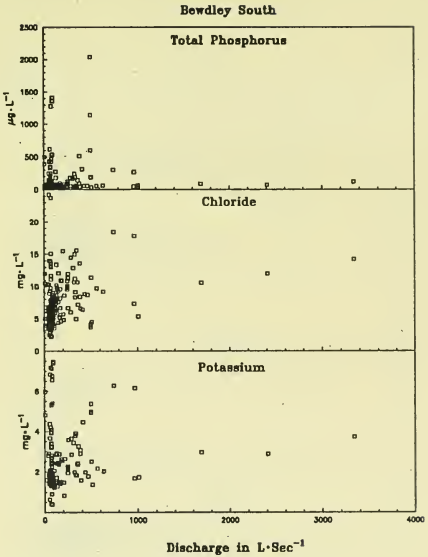

Fig. 4.2.Relationship of total phosphorus, chloride and potassium concentrations to instantaneous discharge at Bewdley South inflow monitoring site: 1986-1989.

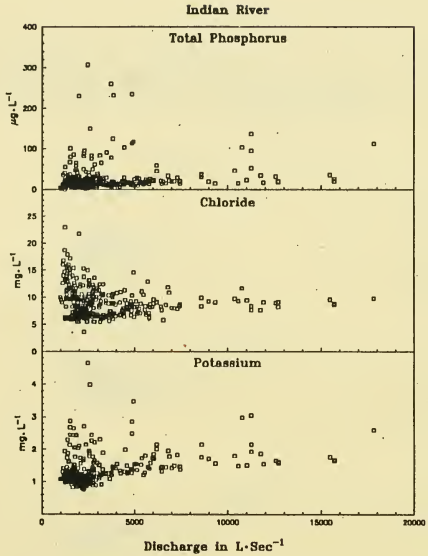

Fig. 4.3.Relationship of total phosphorus, chloride and potassium concentrations to instantaneous discharge at Indian River inflow monitoring site: 1986-1989.

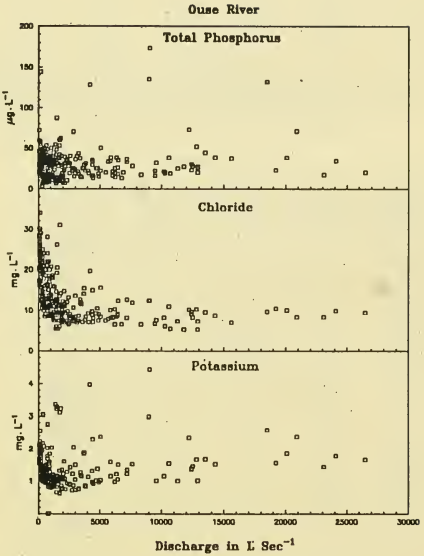

Fig. 4.4.Relationship of total phosphorus, chloride and potassium concentrations to instantaneous discharge at Ouse River inflow monitoring site: 1986-1989.

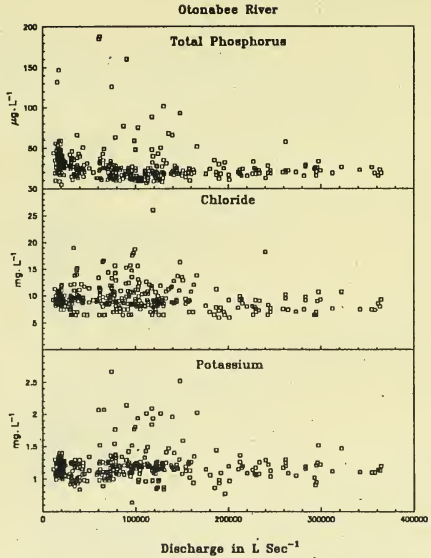

Fig. 4.5. Relationship of total phosphorus, chloride and potassium concentrations to instantaneous discharge at Otonabee River inflow monitoring site: 1986-1989.

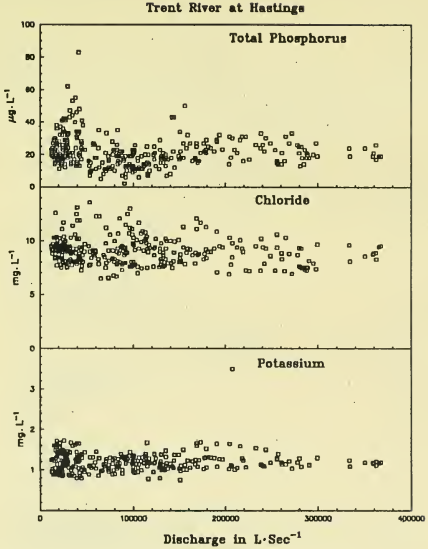

Fig. 4.6.Relationship of total phosphorus, chloride and potassium concentrations to instantaneous discharge at Trent River inflow monitoring site: 1986-1989.

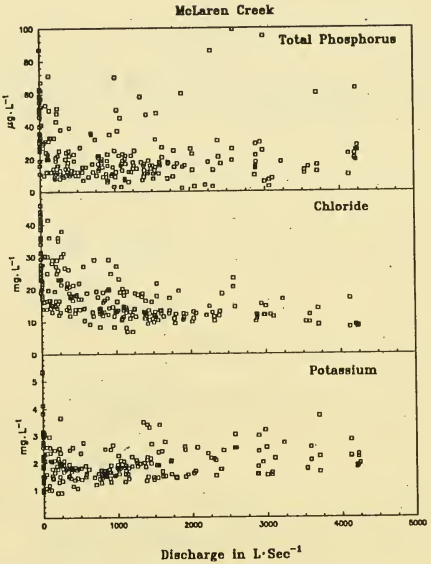

Fig. 4.7. Relationship of total phosphorus, chloride and potassium concentrations to instantaneous discharge at McLaren Creek inflow monitoring site: 1986-1989.

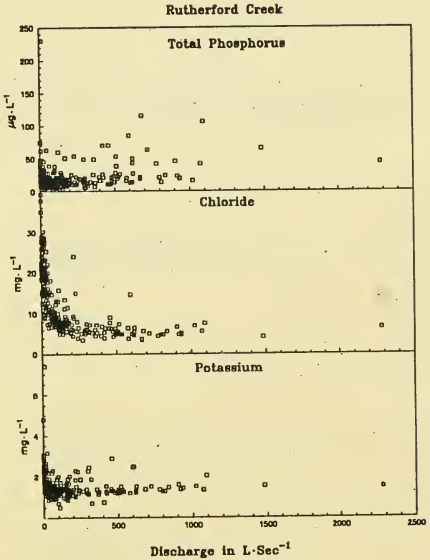

Fig. 4.8. Relationship of total phosphorus, chloride and potassium concentrations to instantaneous discharge at Rutherford Cr inflow monitoring site: 1986-1989.

Fig. 4.9. Relationship of total phosphorus, chloride and potassium concentrations to instantaneous discharge at Hawkers Creek inflow monitoring site: 1986-1989.

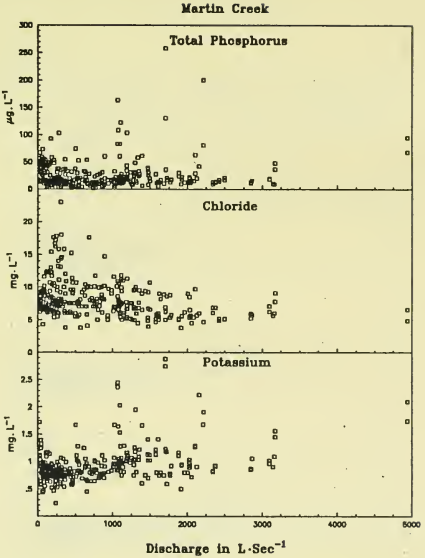

Fig. 4.10. Relationship of total phosphorus, chloride and potassium concentrations to instantaneous discharge at Martin Creek inflow monitoring site: 1986-1989.

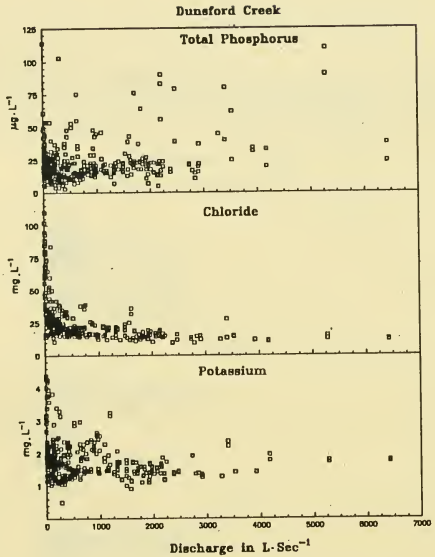

Fig. 4.11. Relationship of total phosphorus, chloride and potassium concentrations to instantaneous discharge at Dunsford Creek inflow monitoring site: 1986-1989.

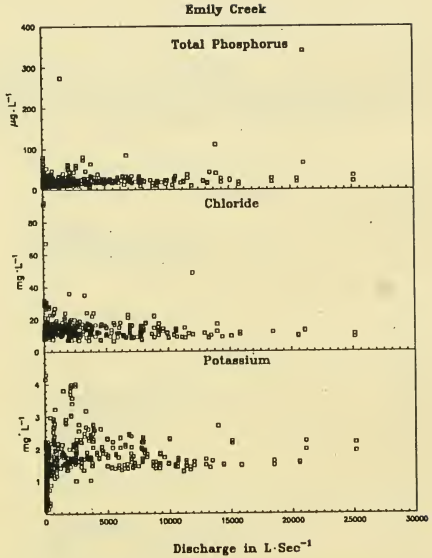

Fig. 4.12. Relationship of total phosphorus, chloride and potassium concentrations to estimated discharge at mouth of Emily Creek: 1986-1989.

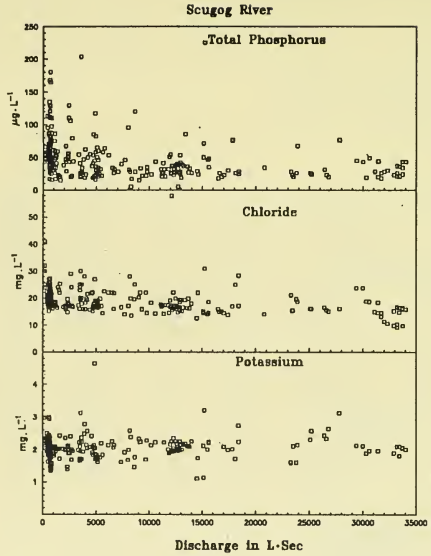

Fig. 4.13. Relationship of total phosphorus, chloride and potassium concentrations to discharge of the Scugog River at Lindsay: 1986-1989.

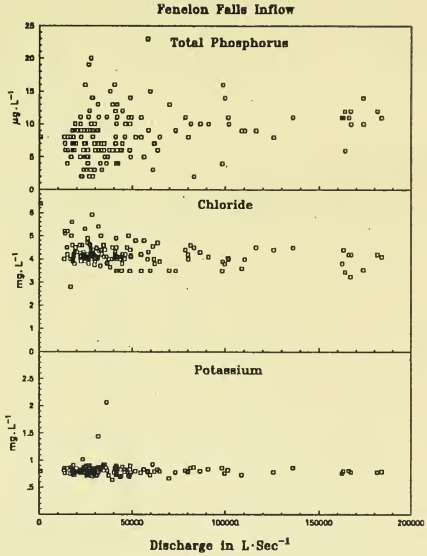

Fig. 4.14. Relationship of total phosphorus, chloride and potassium concentrations to discharge of Cameron lake to Sturgeon Lake at Fenelon Falls: 1986-1989.

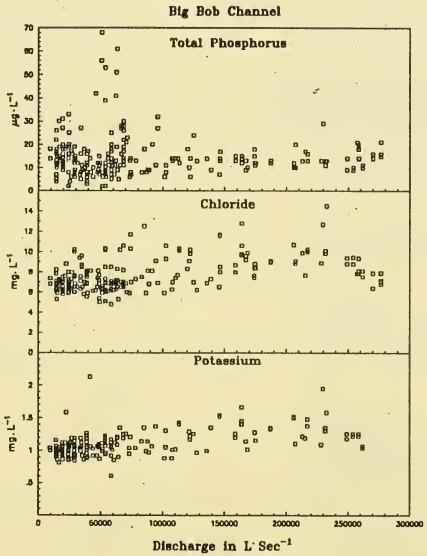

Fig. 4.15. Relationship of total phosphorus, chloride and potassium concentrations to discharge of Sturgeon Lake to the Big Bob Channel at Bobcaygeon: 1986-1989.

APPENDIX 5.0

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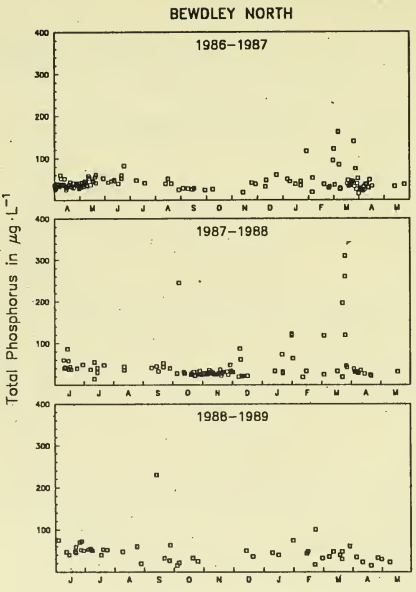
BEWDLEY NORTH
1986–1987
1987–1988
1988–1989
Total Phosphorus in µg·L⁻¹
400
300
200
100
A M J J A S O N D J F M A M
J J A S O N D J F M A M
J J A S O N D J F M A M

Fig. 5.1.Total phosphorus concentrations measured at Rice Lake inflow monitoring sites 1986-1989 : Bewdley North.

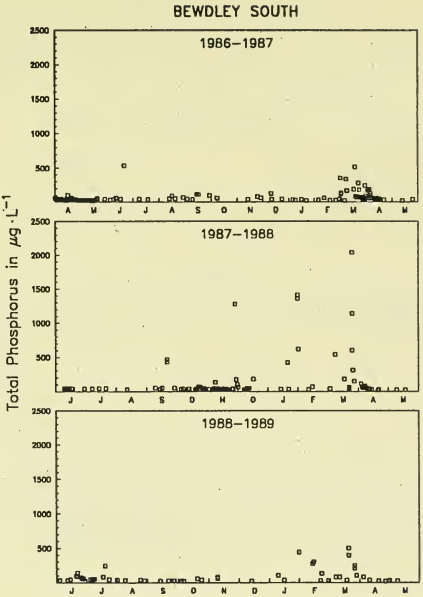
BEWDLEY SOUTH
1986–1987
1987–1988
1988–1989
Total Phosphorus in µg·L⁻¹
2500
2000
1500
1000
500
A M J J A S O N D J F M A M
J J A S O N D J F M A M
J J A S O N D J F M A M

Fig. 5.2. Total phosphorus concentrations measured at Rice Lake inflow monitoring sites 1986-1989 : Bewdley South.

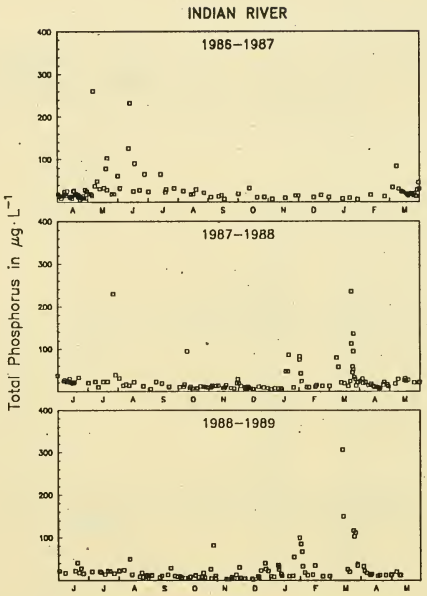

Fig. 5.3. Total phosphorus concentrations measured at Rice Lake inflow monitoring sites 1986-1989 : Indian River.

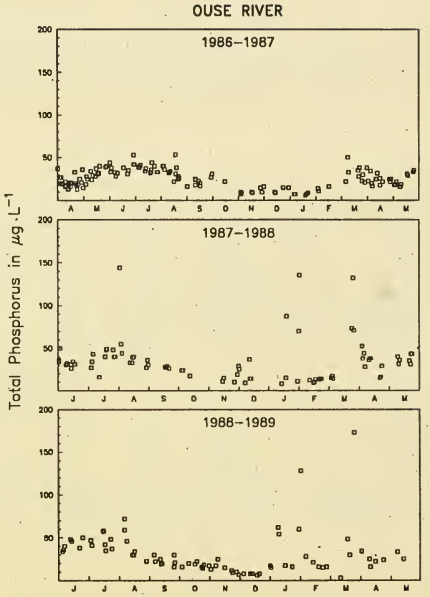

Fig. 5.4. Total phosphorus concentrations measured at Rice Lake inflow monitoring sites 1986-1989 : Ouse River.

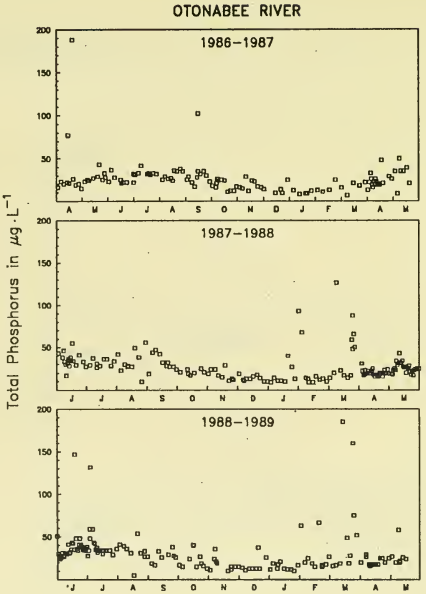

Fig. 5.5. Total phosphorus concentrations measured at Rice Lake inflow monitoring sites 1986-1989 : Otonabee River.

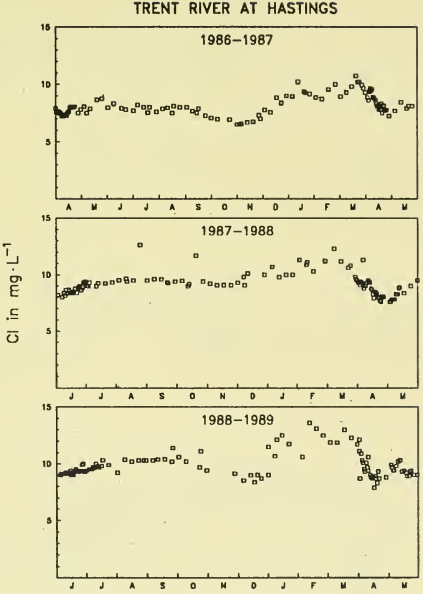

Fig. 5.6. Total phosphorus concentrations measured at Rice Lake inflow monitoring sites 1986-1989 : Trent River at Hastings.

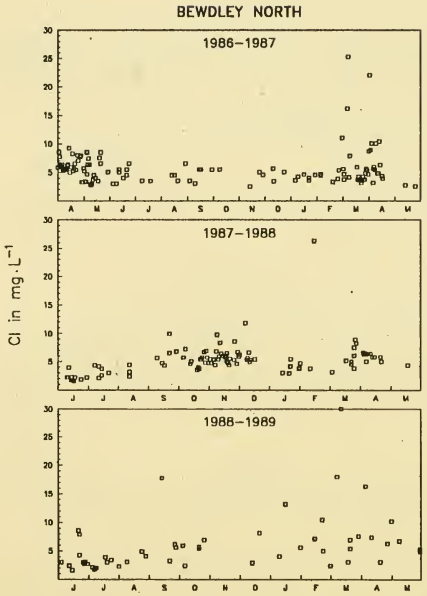

Fig. 5.7. Chloride concentrations measured at Rice Lake tributary inflow sites 1986-1989 : Bewdley North.

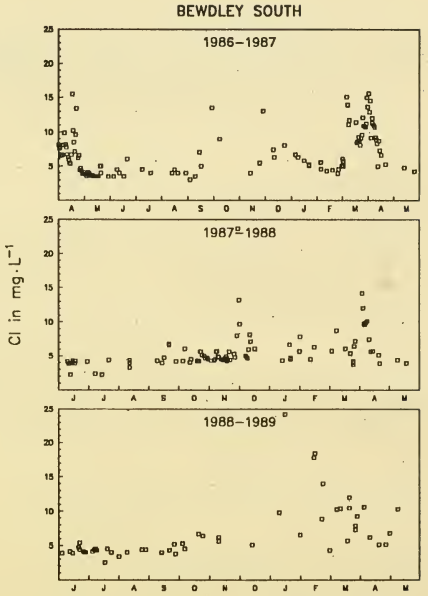

Fig. 5.8. Chloride concentrations measured at Rice Lake inflow monitoring sites 1986-1989 : Bewdley South.

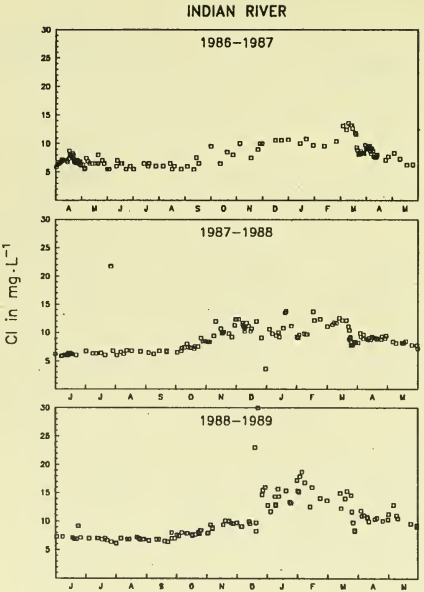

Fig. 5.9. Chloride concentrations measured at Rice Lake inflow monitoring sites 1986-1989 : Indian River.

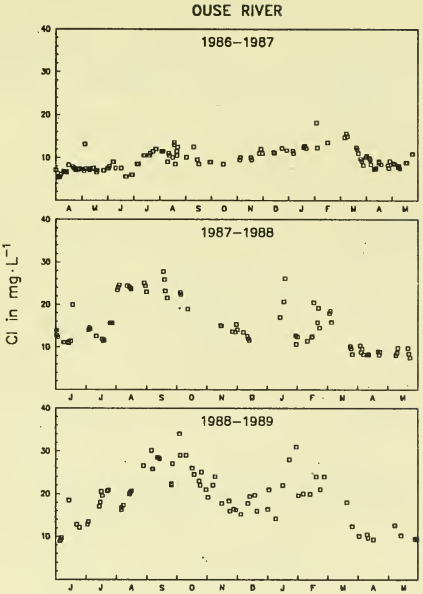

Fig. 5.10. Chloride concentrations measured at Rice Lake inflow monitoring sites 1986-1989 : Ouse River.

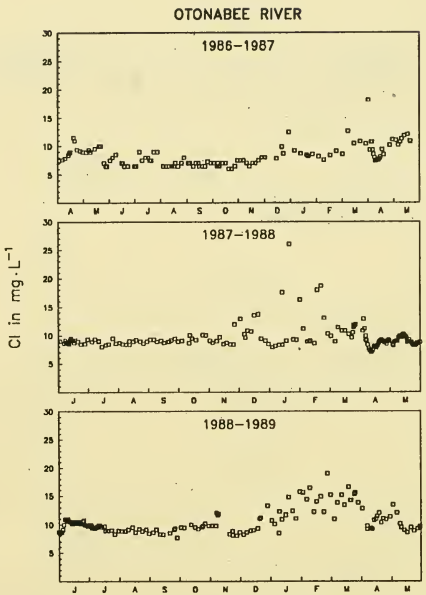

Fig. 5.11. Chloride concentrations measured at Rice Lake inflow monitoring sites 1986-1989 : Otonabee River.

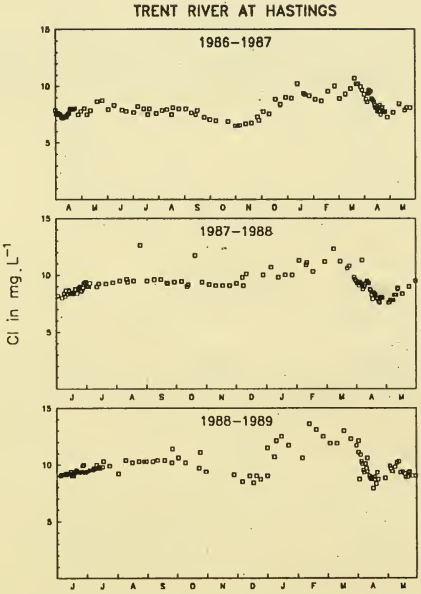

Fig. 5.12. Chloride concentrations measured at Rice Lake inflow monitoring sites 1986-1989 : Trent River at Hastings.

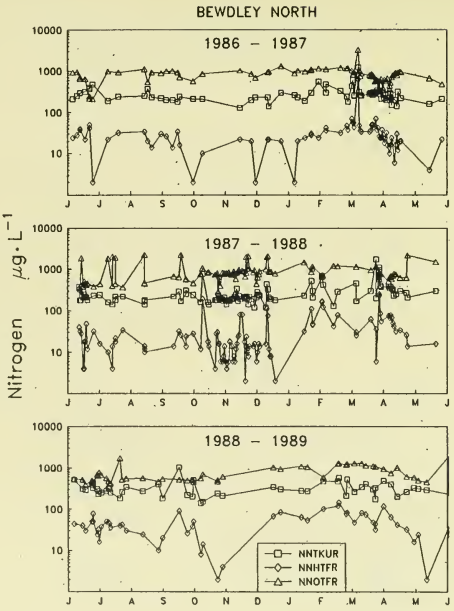

Fig. 5.13: Nitrate, Kjeldahl nitrogen and ammonium concentrations at Rice Lake inflow, Bewdley North, 1986-1989.

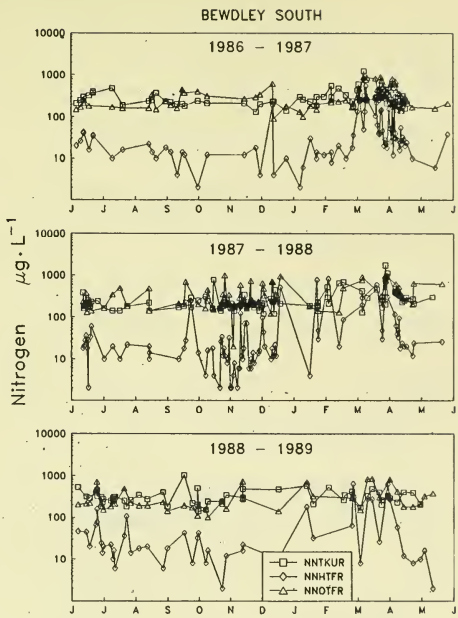

Fig. 5.14: Nitrate, Kjeldahl nitrogen and ammonium concentrations at Rice Lake inflow, Bewdley South, 1986-1989.

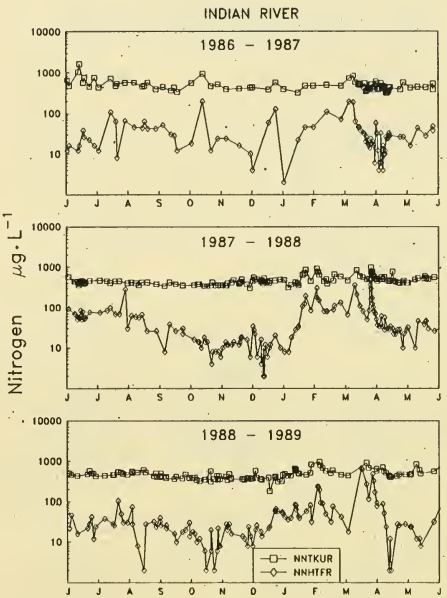

Fig 5.15A Kjeldahl nitrogen and ammonium concentrations at Rice Lake inflow, Indian River, 1986-1989.

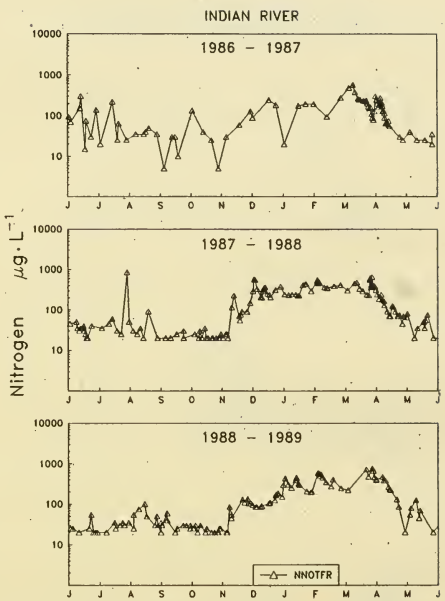

Fig. 5.15B: Nitrate concentrations at Rice Lake inflow, Indian River, 1986-1989.

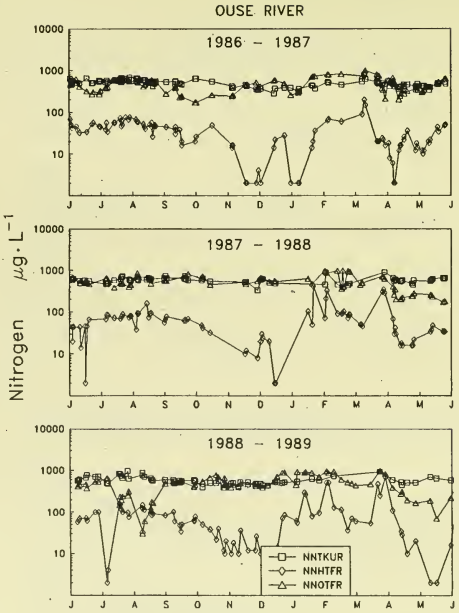

Fig. 5.16: Nitrate, Kjeldahl nitrogen and ammonium concentrations at Rice Lake inflow, Ouse River, 1986-1989.

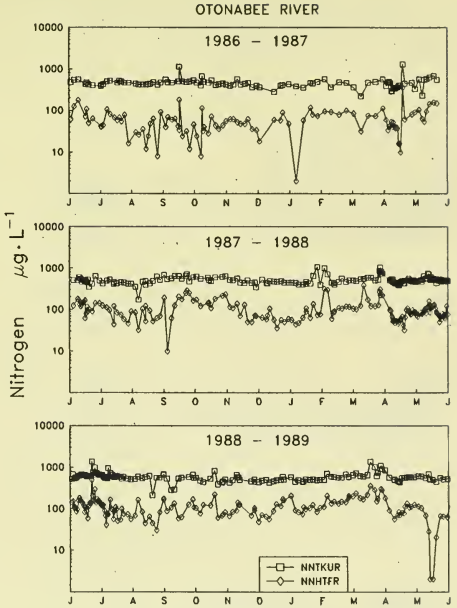

Fig. 5.17A: Kjeldahl and Ammonium nitrogen concentrations at Rice Lake inflow, Otonabee River, 1986-1989.

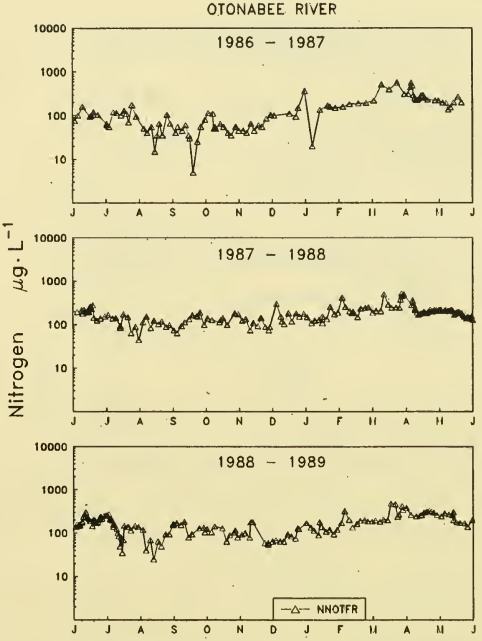

Fig. 5.17B: Nitrate concentrations at Rice Lake inflow, Otonabee River, 1986-1989.

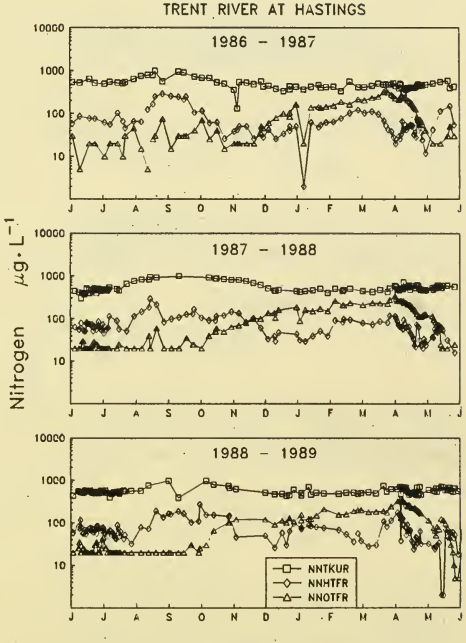

Fig. 5.18: Nitrate, Kjeldahl and Ammonium nitrogen concentrations at Rice Lake outflow, the Trent River at Hastings, 1986-1989.

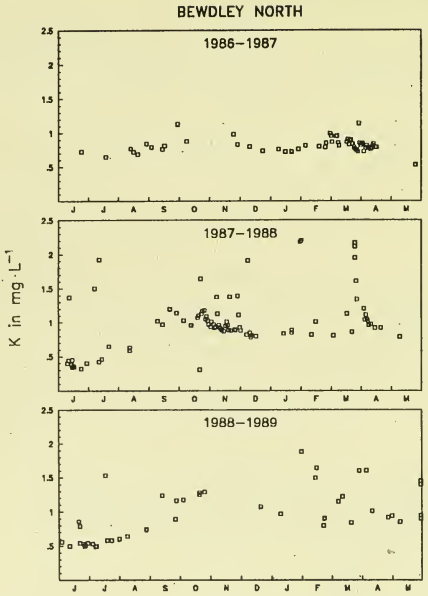

Fig. 5.19. Potassium concentrations measured at Rice Lake inflow monitoring sites 1986-1989 : Bewdley North.

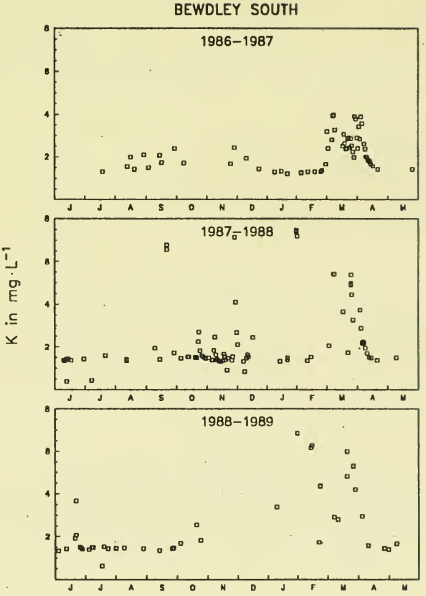

Fig. 5.20. Potassium concentrations measured at Rice Lake inflow monitoring sites 1986-1989 : Bewdley South.

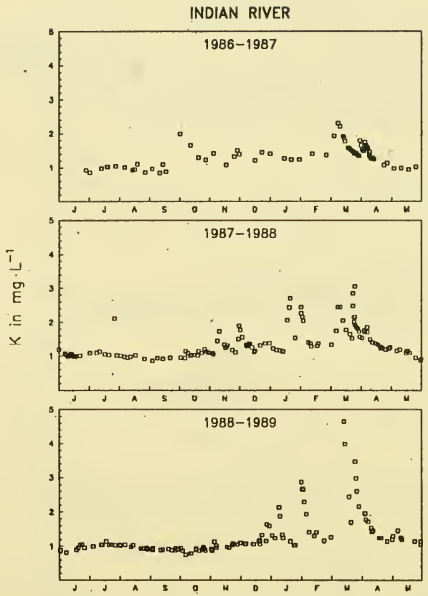

Fig. 5.21. Potassium concentrations measured at Rice Lake inflow monitoring sites 1986-1989 : Indian River.

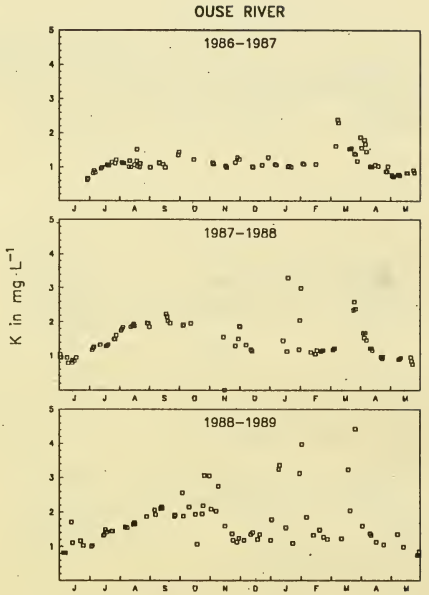

Fig. 5.22. Potassium concentrations measured at Rice Lake inflow monitoring sites 1986-1989 : Ouse River.

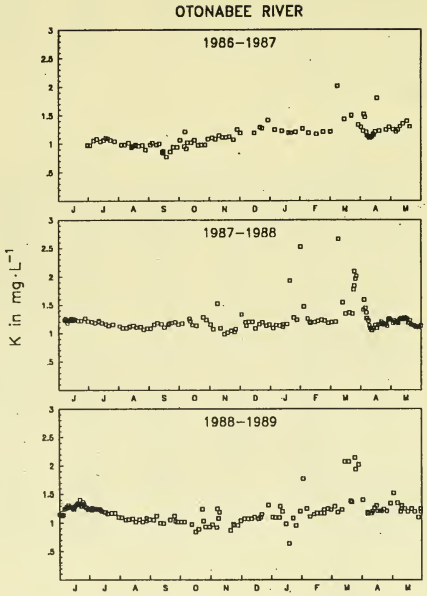

Fig. 5.23. Potassium concentrations measured at Rice Lake inflow monitoring sites 1986-1989 : Otonabee River.

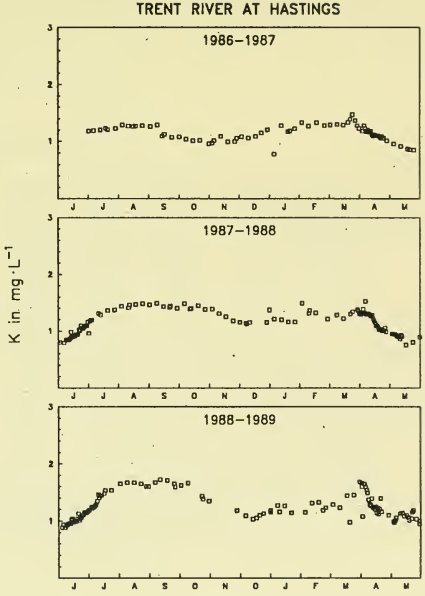

Fig. 5.24. Potassium concentrations measured at Rice Lake inflow monitoring sites 1986-1989 : Trent River at Hastings.

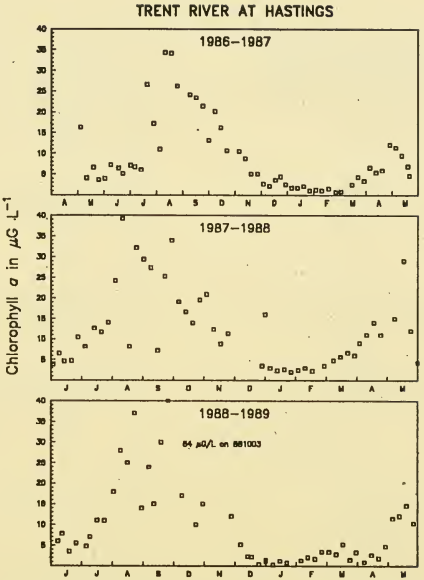
TRENT RIVER AT HASTINGS
1986–1987
1987–1988
1988–1989
84 µG/L on 881003
Chlorophyll a in µG L⁻¹
A M J J A S O N D J F M A M
J J A S O N D J F M A M
J J A S O N D J F M A M

Fig. 5.25. Chlorophyll a concentrations measured in the Trent River outflow of Rice Lake at Hastings: 1986-1989.

APPENDIX 6.0

Figure 6.1. Total phosphorus concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : McLaren Creek. A-88

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Figure 6.3. Total phosphorus concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : Hawkers Creek. A-89

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Figure 6.12. Chloride concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : Hawkers Creek. A-93

Figure 6.13. Chloride concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : Martin Creek. A-94

Figure 6.14. Chloride concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : Dunsford Creek. A-94

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Figure 6.24. Potassium concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : Emily Creek. A-99

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A. Kjeldahl and Ammonium Nitrogen B. Nitrate Nitrogen A-105

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A. Kjeldahl and Ammonium Nitrogen B. Nitrate Nitrogen A-107

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Figure 6.37. Chlorophyll a concentrations measured in the Sturgeon Lake outflow at Big Bob Channel, Bobcaygeon: 1986-1989. ..... A-110

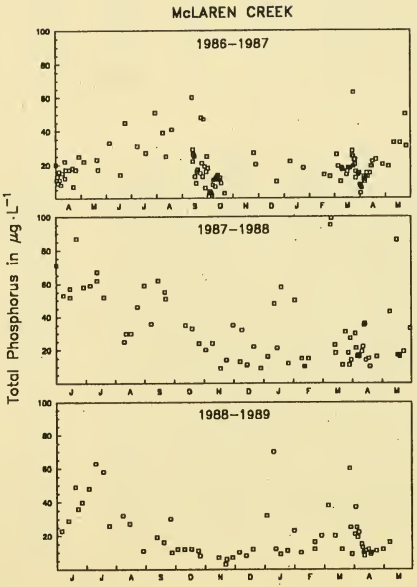

Fig. 6.1. Total phosphorus concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : McLaren Creek.

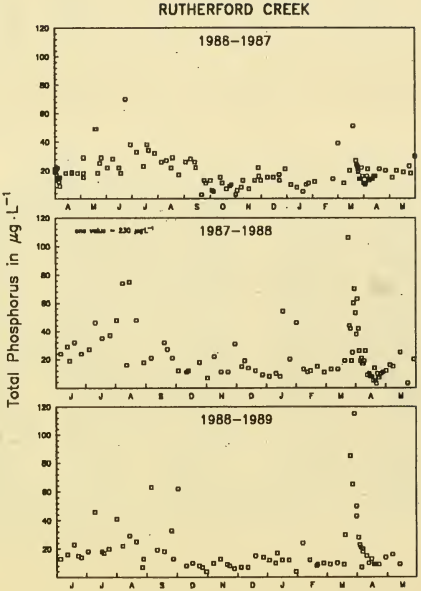

Fig. 6.2. Total phosphorus concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : Rutherford Creek.

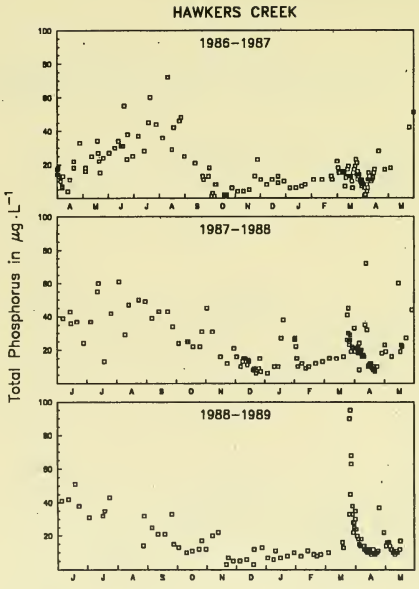

Fig. 6.3. Total phosphorus concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : Hawkers Creek.

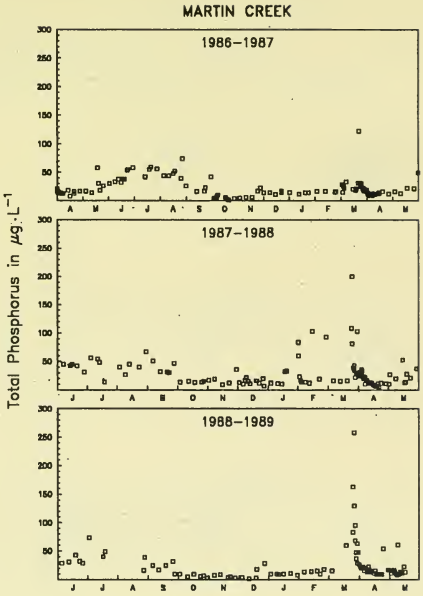

Fig. 6.4. Total phosphorus concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : Martin Creek.

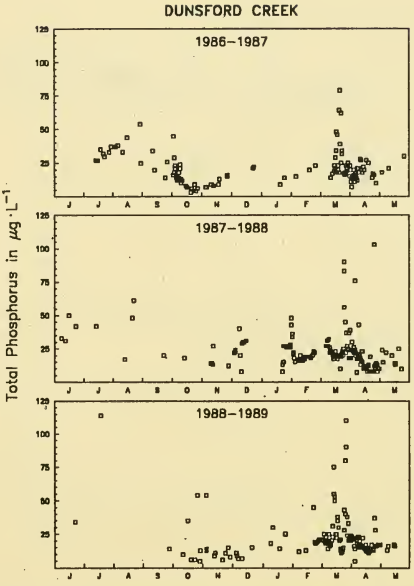

Fig. 6.5. Total phosphorus concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : Dunsford Creek.

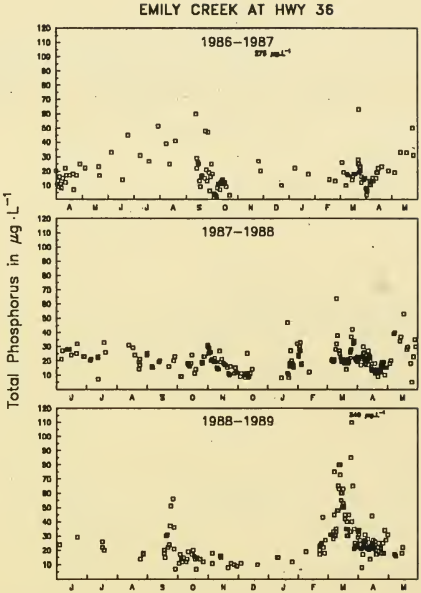

Fig. 6.6. Total phosphorus concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : Emily Creek.

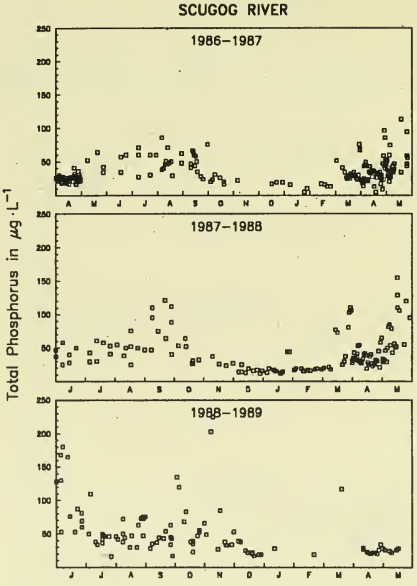

Fig. 6,7. Total phosphorus concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : Scugog River.

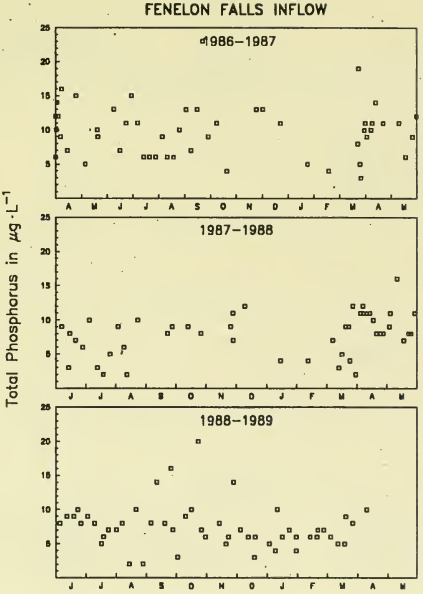
FENELON FALLS INFLOW
1986–1987
1987–1988
1988–1989
Total Phosphorus in $\mu g \cdot L^{-1}$
A M J J A S O N D J F M A M
J J A S O N D J F M A M
J J A S O N D J F M A M

Fig. 6.8. Total phosphorus concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : Inflow at Fenelon Falls.

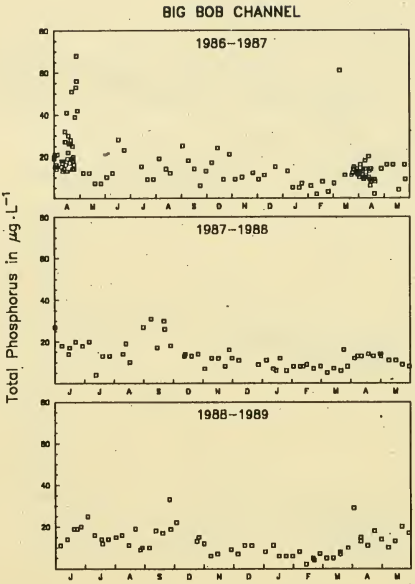

Fig. 6.9. Total phosphorus concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : Outflow at Bobcaygeon.

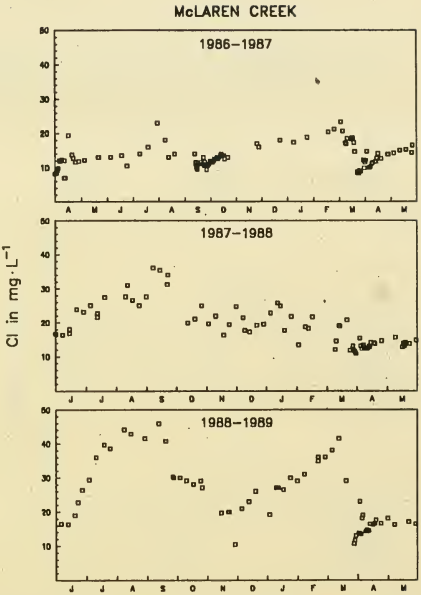

Fig. 6.10. Chloride concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : McLaren Creek.

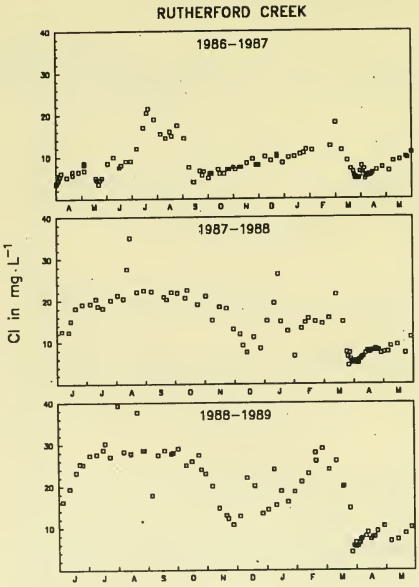

Fig. 6.11. Chloride concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : Rutherford Creek.

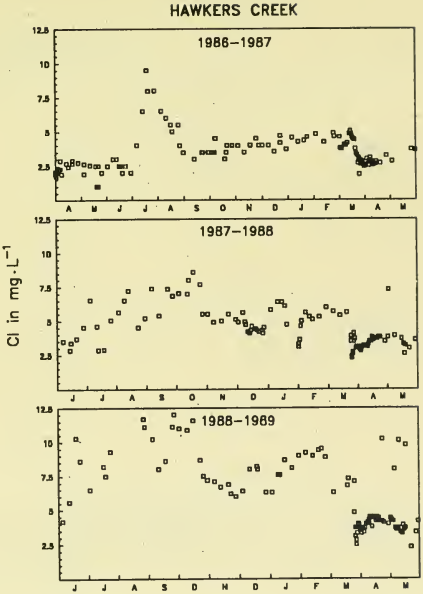

Fig. 6.12. Chloride concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : Hawkers Creek.

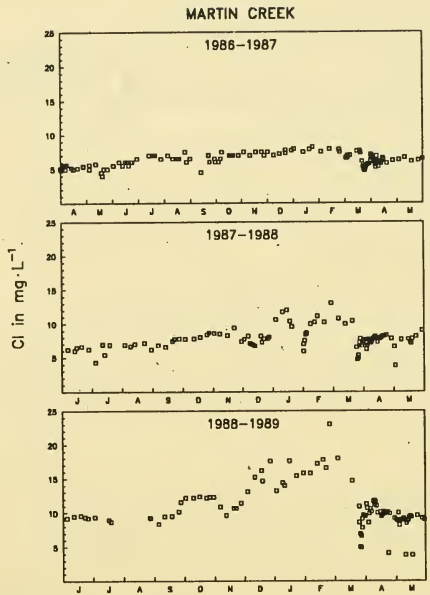

Fig. 6.13. Chloride concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : Martin Creek.

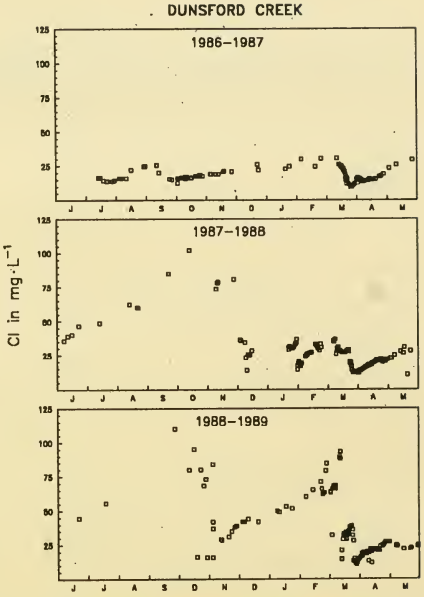

Fig. 6.14. Chloride concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : Dunsford Creek.

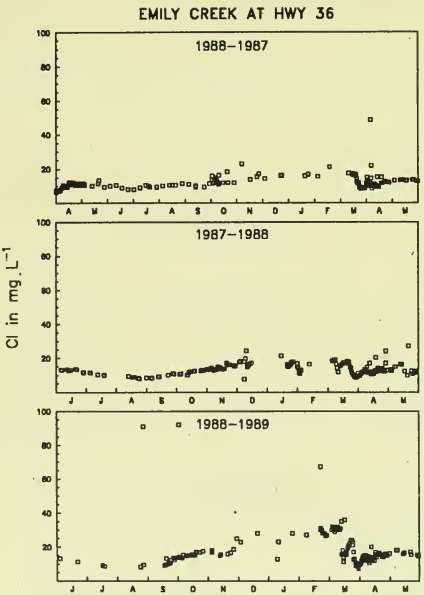

Fig. 6.15. Chloride concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : Emily Creek.

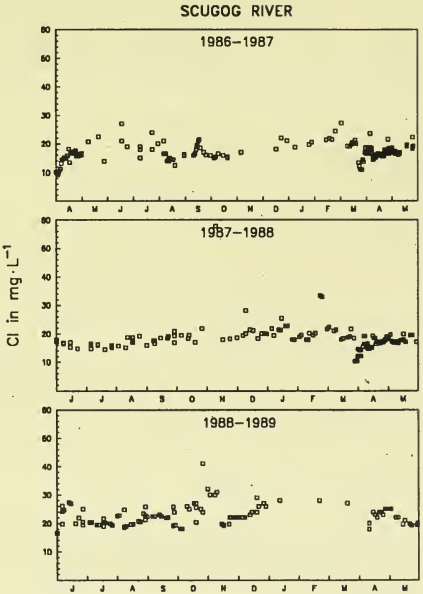

Fig. 6.16. Chloride concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : Scugog River.

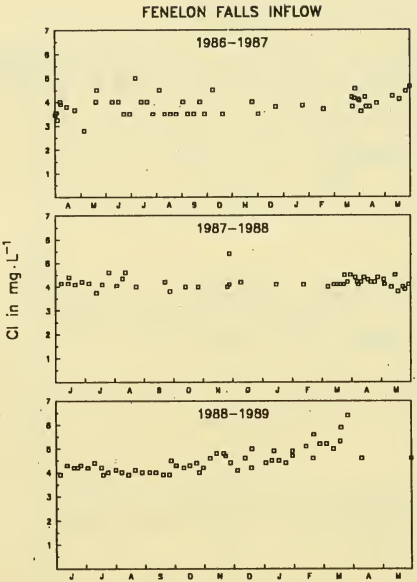

Fig. 6.17. Chloride concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : Inflow at Fenelon Falls.

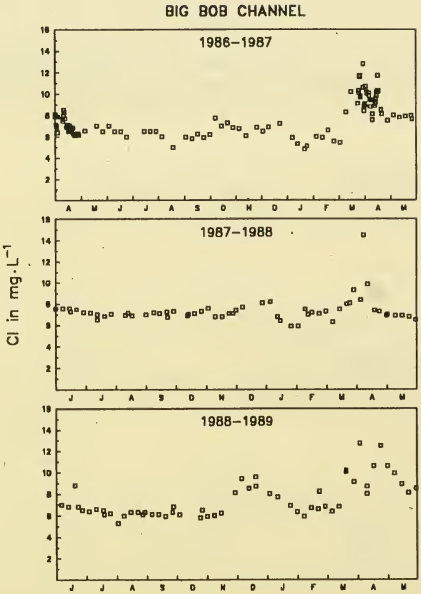

Fig. 6.18 Chloride concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : Outflow at Bobcaygeon.

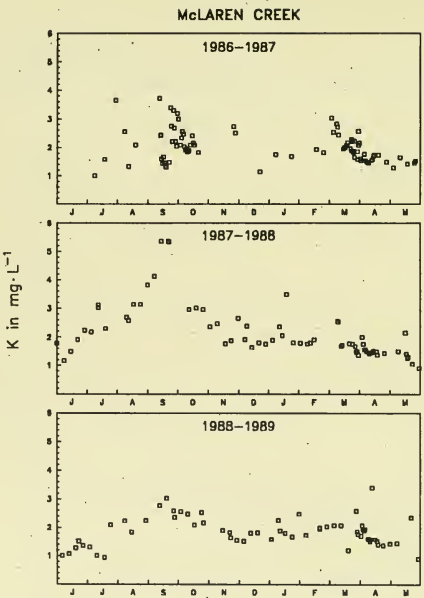

Fig. 6.19. Potassium concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : McLaren Creek.

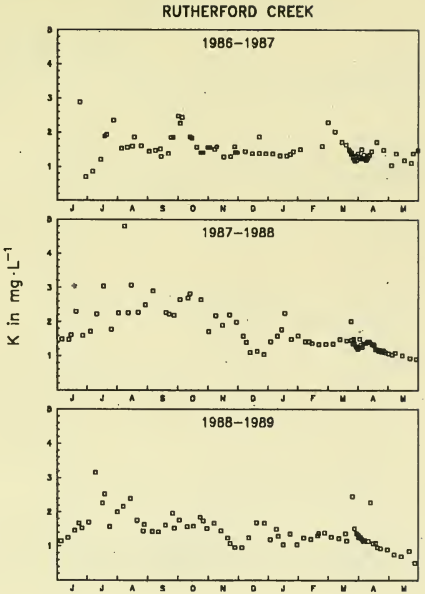

Fig. 6.20. Potassium concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : Rutherford Creek.

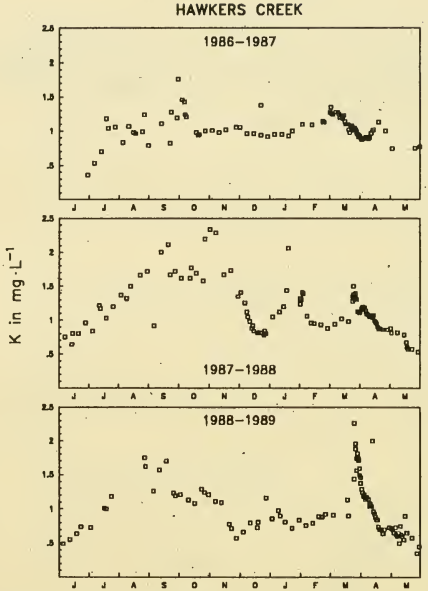

Fig. 6.21. Potassium concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : Hawkers Creek.

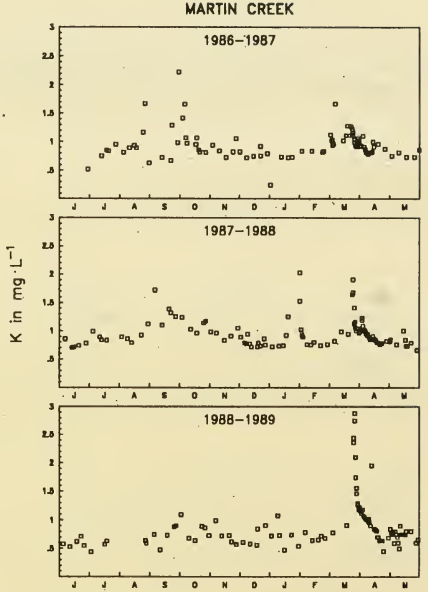

Fig. 6.22. Potassium concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : Martin Creek.

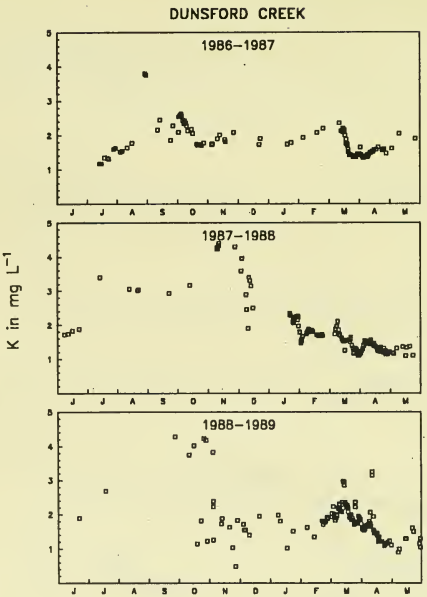

Fig. 6.23. Potassium concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : Dunsford Creek.

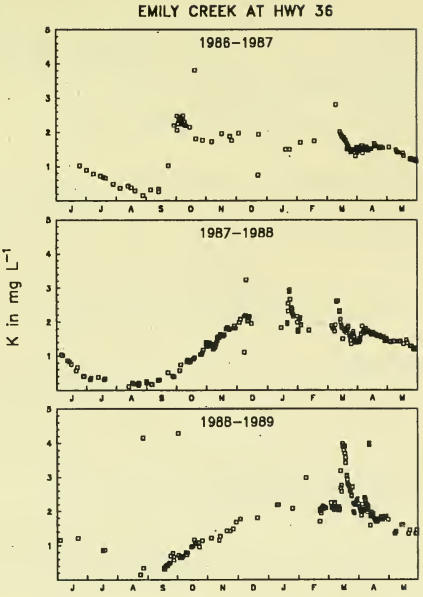

Fig. 6.24. Potassium concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : Emily Creek.

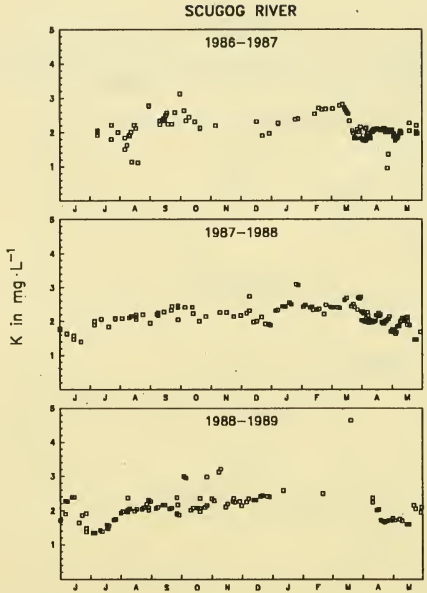

Fig. 6.25. Potassium concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : Scugog River.

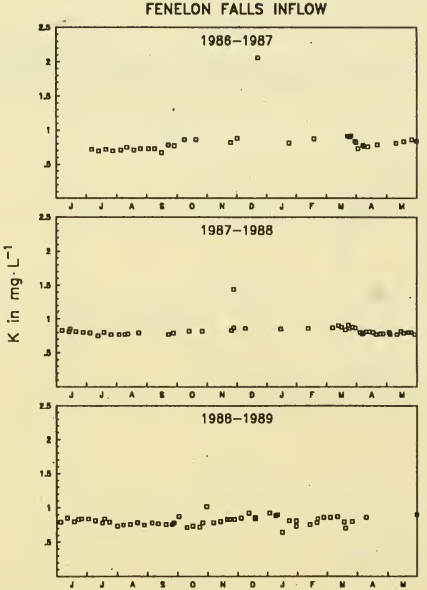

Fig. 6.26. Potassium concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : Inflow at Fenelon Falls.

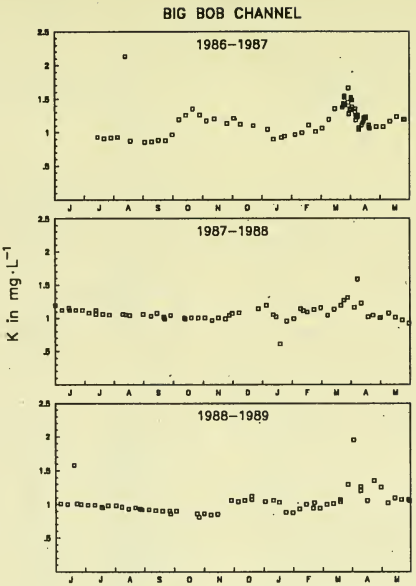

Fig. 6.27. Potassium concentrations measured at Sturgeon Lake inflow monitoring sites 1986-1989 : Outflow at Bobcaygeon.

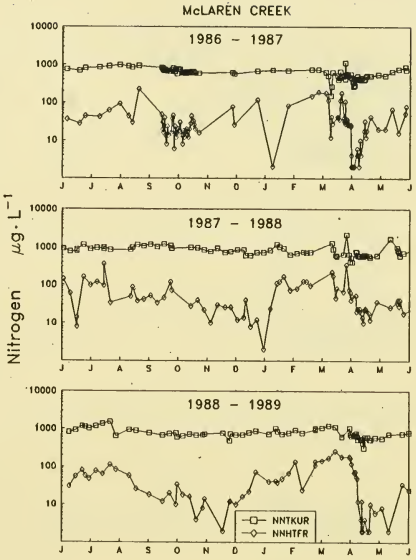

Fig. 6.28A: Kjeldahl nitrogen and ammonium concentrations for Sturgeon Lake inflow, McLaren Creek, 1986-1989.

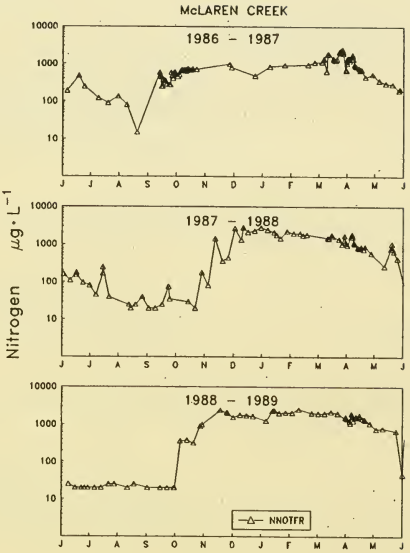

Fig. 6.28B: Nitrate concentrations for Sturgeon Lake inflow, McLaren Creek, 1986-1989.

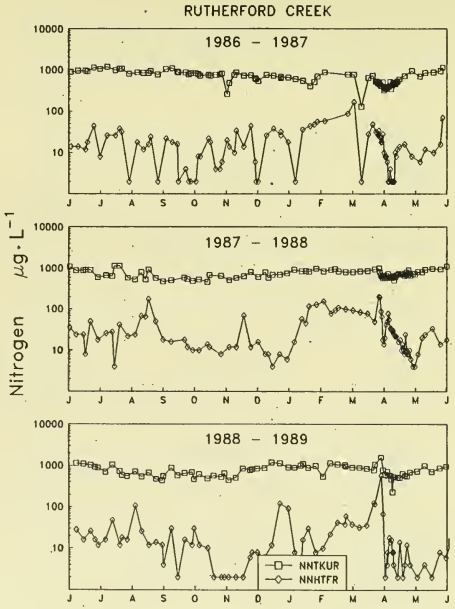

Fig. 6.29A: Kjeldahl nitrogen and ammonium concentrations for Sturgeon Lake inflow, Rutherford Creek, 1986-1989.

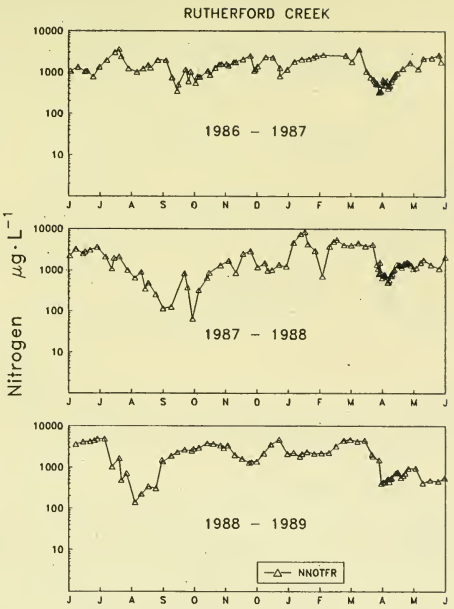

Fig. 6.29B: Nitrate concentrations for Sturgeon Lake inflow, Rutherford Creek, 1986-1989.

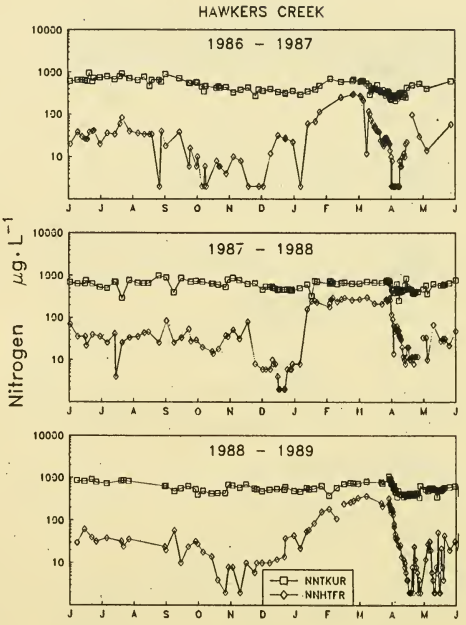

Fig. 6.30A: Kjeldahl nitrogen and ammonium concentrations for Sturgeon Lake inflow, Hawkers Creek, 1986-1989.

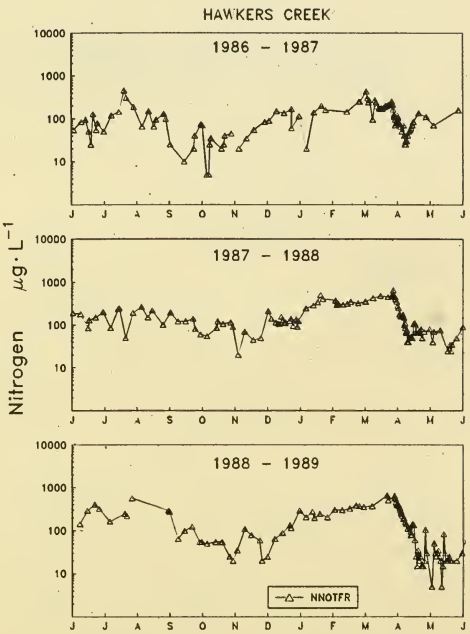

Fig. 6.30B: Nitrate concentrations for Sturgeon Lake inflow, Hawkers Creek, 1986-1989.

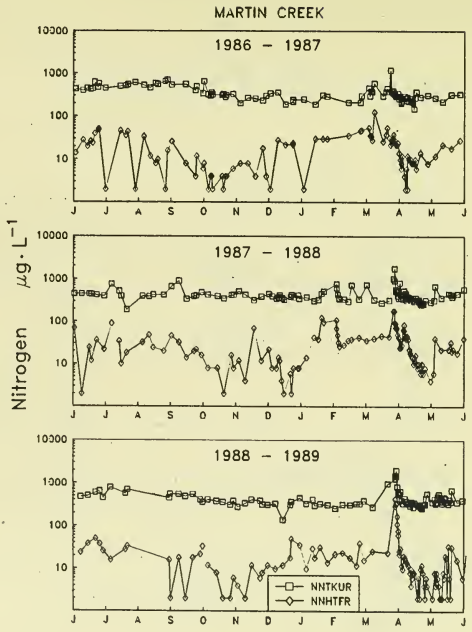

Fig. 6.31A: Kjeldahl nitrogen and ammonium concentrations for Sturgeon Lake inflow, Martin Creek, 1986-1989.

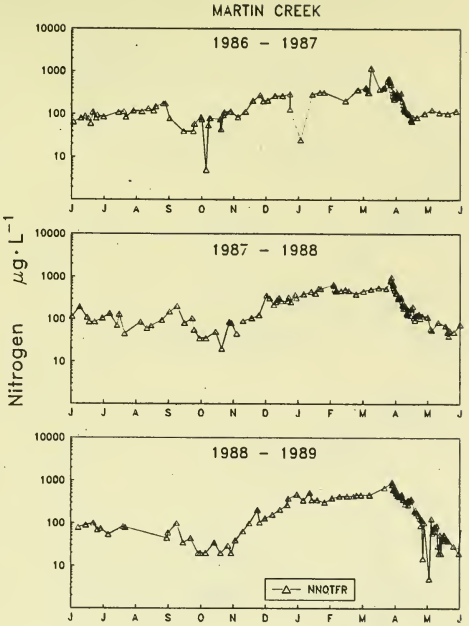

Fig. 6.31B: Nitrate concentrations for Sturgeon Lake inflow, Martin Creek, 1986-1989.

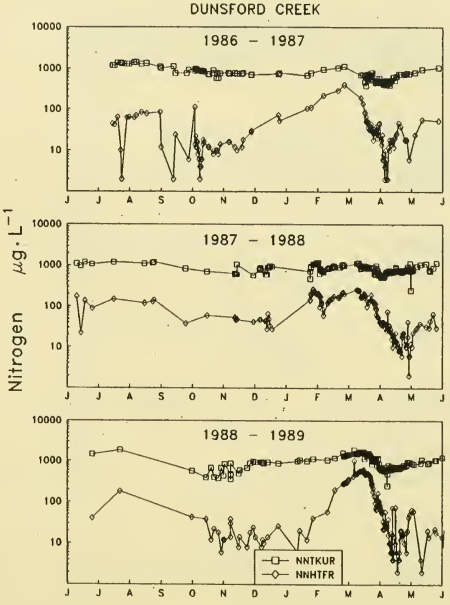

Fig. 6.32A: Kjeldahl nitrogen and ammonium concentrations for Sturgeon Lake Inflow, Dunsford Creek, 1986-1989.

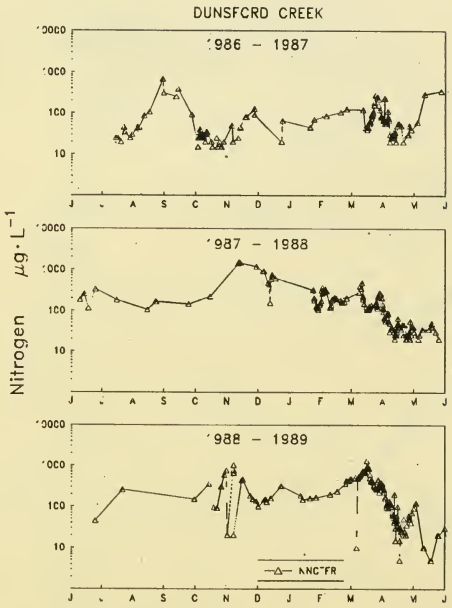

Fig. 632B: Nitrate concentrations for Sturgeon Lake Inflow, Dunsford Creek, 1986-1989.

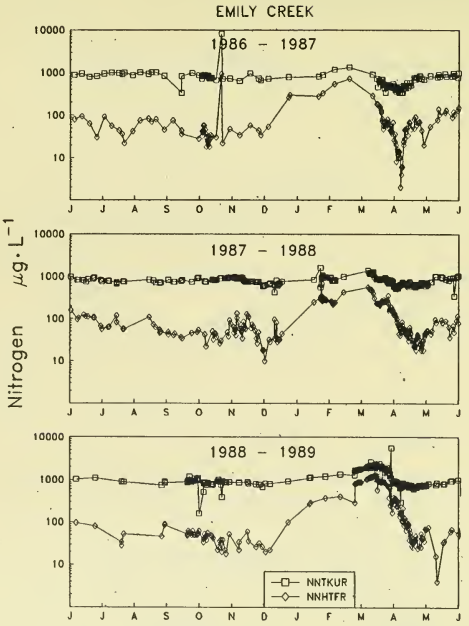

Fig. 6.33A: Kjeldahl nitrogen and ammonium concentrations for Sturgeon Lake inflow, Emily Creek, 1986-1989.

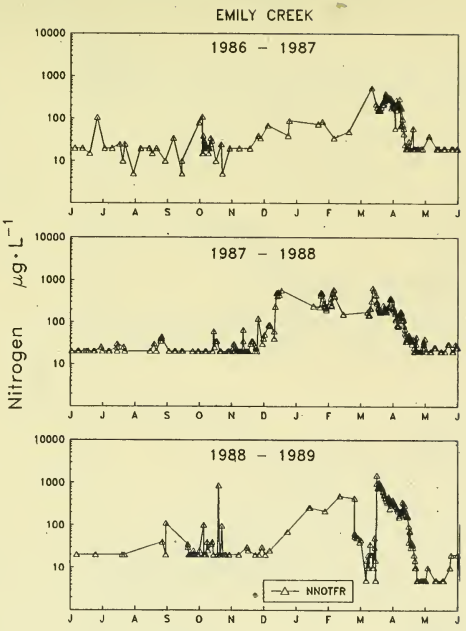

Fig. 6.33B: Nitrate concentrations for Sturgeon Lake Inflow, Emily Creek, 1986-1989.

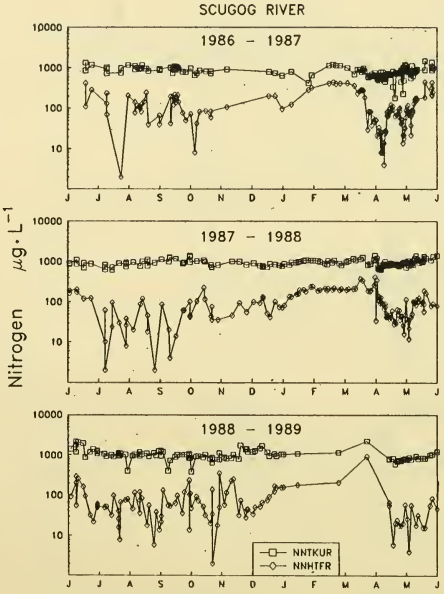

Fig. 6.34A Kjeldahl nitrogen and ammonium concentrations for Sturgeon Lake inflow, Scugog River, 1986-1989.

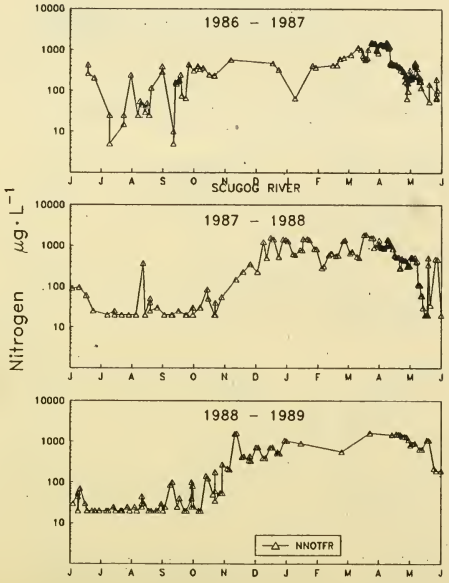

Fig. 6.34B: Nitrate concentrations for Sturgeon Lake Inflow, Scugog River, 1986-1989.

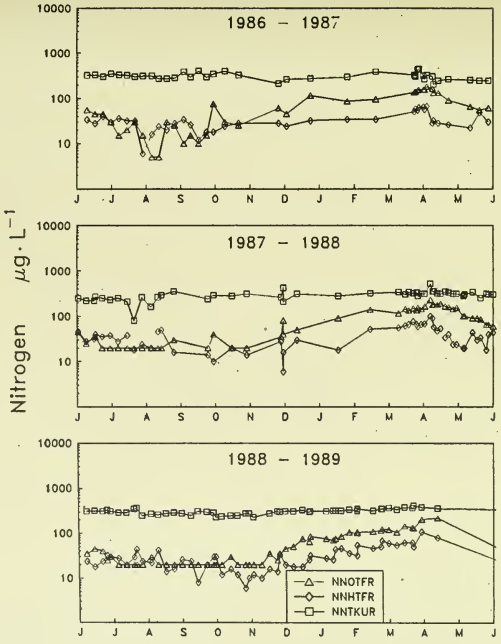

Fig. 6.35: Nitrate, Kjeldahl nitrogen and ammonium concentrations for Sturgeon Lake Inflow, Fenelon Falls, 1986-1989.

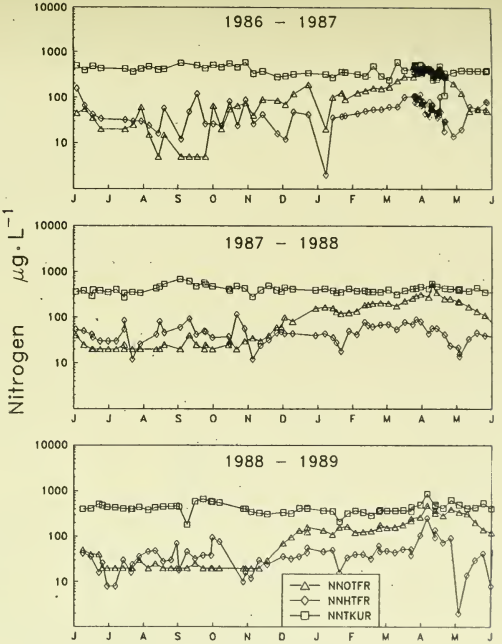

Fig. 6.36: Nitrate, Kjeldahl nitrogen and ammonium concentrations for Sturgeon Lake outflow at Bobcaygeon, 1986-1989.

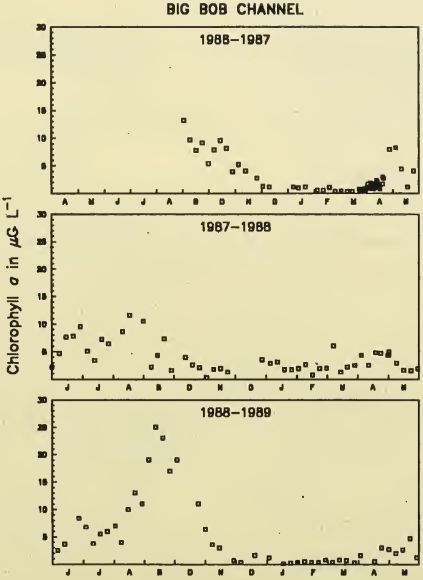

Fig. 6.37. Chlorophyll a concentrations measured in the Sturgeon Lake outflow at Big Bob Channel, Bobcaygeon: 1986-1989.